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ABSTRACT

The purpose of this curriculum guide is to assist administrators and instructors in establishing nuclear medicine technician programs that will meet the accreditation standards of the American Medical Association (AMA) Council on Medical Education. The guide has been developed to prepare nuclear medicine technicians (NMT's) in two-year postsecondary schools with clinical practicums provided by affiliated hospitals, though the program can be adapted to the needs of either one-year hospital-based programs or four-year baccalaureate programs. Included in the guide is information administrators' need to know to determine NMT program feasibility in their institution, program implementation procedures, course outlines, student performance objectives, and laboratory facility requirements. A bibliography listing materials useful for both administrators and instructors, appendices containing samples of useful documents, and lists and descriptions of organizations associated with post-secondary instruction on nuclear medicine technology are also included. (Author/MA)

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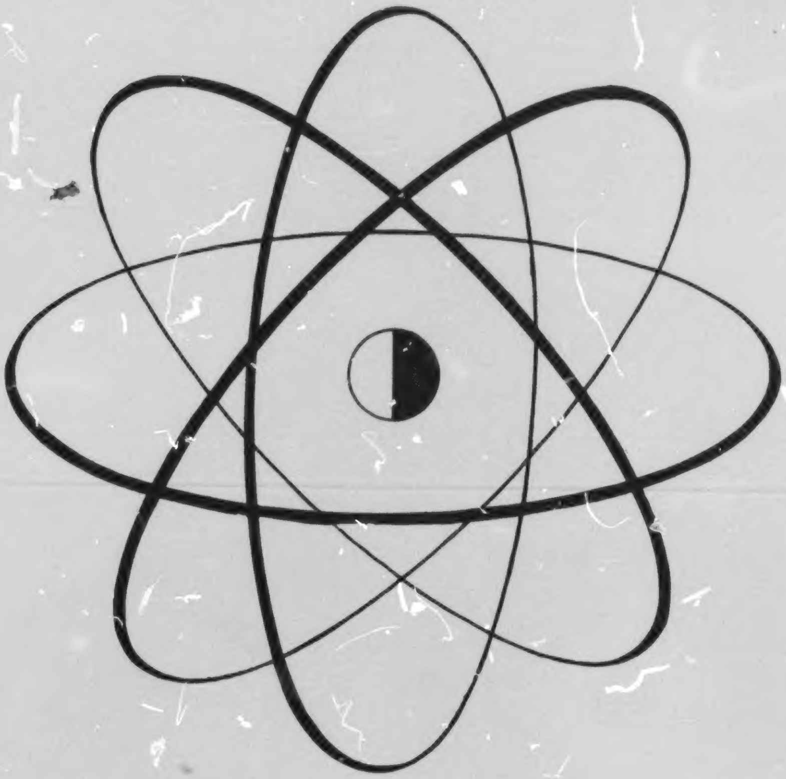
Nuclear Medicine Technology:

A Suggested Postsecondary Curriculum



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NUCLEAR MEDICINE TECHNOLOGY:

A Suggested Postsecondary Curriculum

TECHNICAL EDUCATION RESEARCH CENTERS
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January, 1975

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PREFACE

Technical Education Research Centers (TERC) has been funded by the U. S. Office of Education to develop program planning materials for the preparation of nuclear medicine technicians (NMTs). Among the materials developed is this curriculum guide. The purpose of the guide is to assist administrators and instructors to establish nuclear medicine programs which will meet the accreditation standards of the AMA Council on Medical Education. The guide has been developed with the intention of preparing NMTs in two-year postsecondary schools with clinical practicums provided by affiliated hospitals. It is easily adaptable, however, to the needs of either one-year hospital-based programs or four-year baccalaureate programs.

Included in the guide is information administrators need to know to determine whether or not to establish an NMT program in their institution. This is followed by steps for implementing a program if a decision has been made to proceed. Course outlines and student performance objectives are provided as well as information about laboratory facilities, a bibliography listing materials useful for both administrators and instructors, and appendices containing samples of useful documents, and lists and descriptions of organizations associated with postsecondary instruction or nuclear medicine technology.

It should be mentioned that the authors of the guide are well aware that NMTs are referred to as "technologists," perhaps as often as they are called "technicians." For the sake of consistency, NMTs are referred to here as "technicians" indicating persons who are specialized technological assistants prepared in two-year postsecondary programs.

The curriculum guide is the result of the efforts of many individuals and organizations concerned with the education of NMTs. Special thanks go to Dr. Walter J. Brooking, Education Specialist in the Bureau of Occupational and Adult Education, U. S. Office of Education for his critiques and comments on the curriculum drafts. Special thanks are also due to the representatives of the following six societies serving on the AMA Joint Review Committee on Schools in Nuclear Medicine Technology for their suggestions:

American College of Radiology

American Society of Clinical Pathologists

Society of Nuclear Medicine Technologists

American Society of Radiologic Technologists

American Society of Medical Technologists

Society of Nuclear Medicine

A list of the large number of people in the field who have generously provided their time and expertise can be found in the acknowledgment section.

TERC Staff

December. 1974

Measuring the radioactivity of a dose to be administered to a patient.

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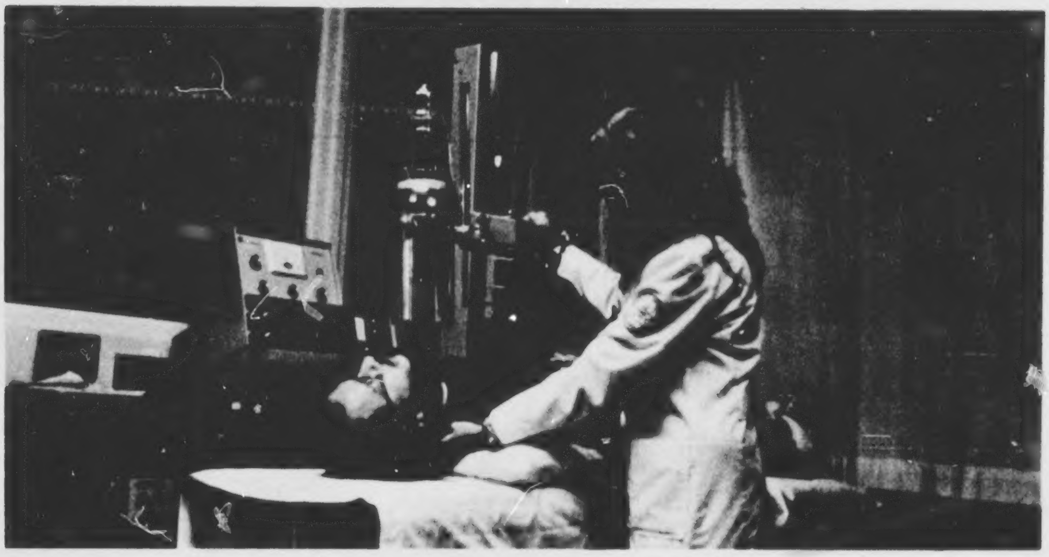
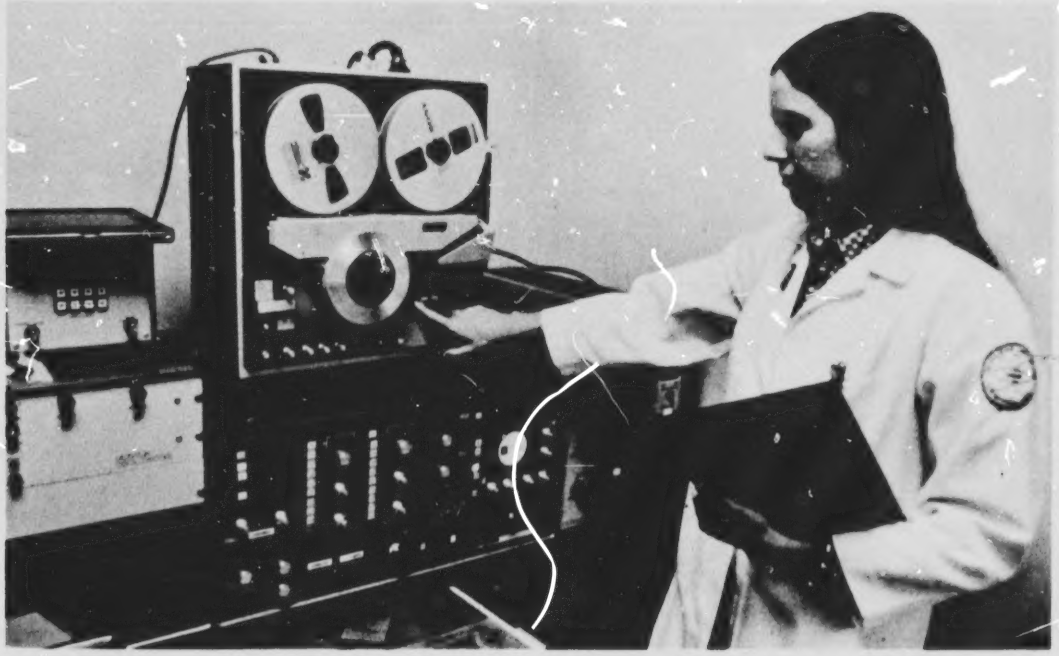
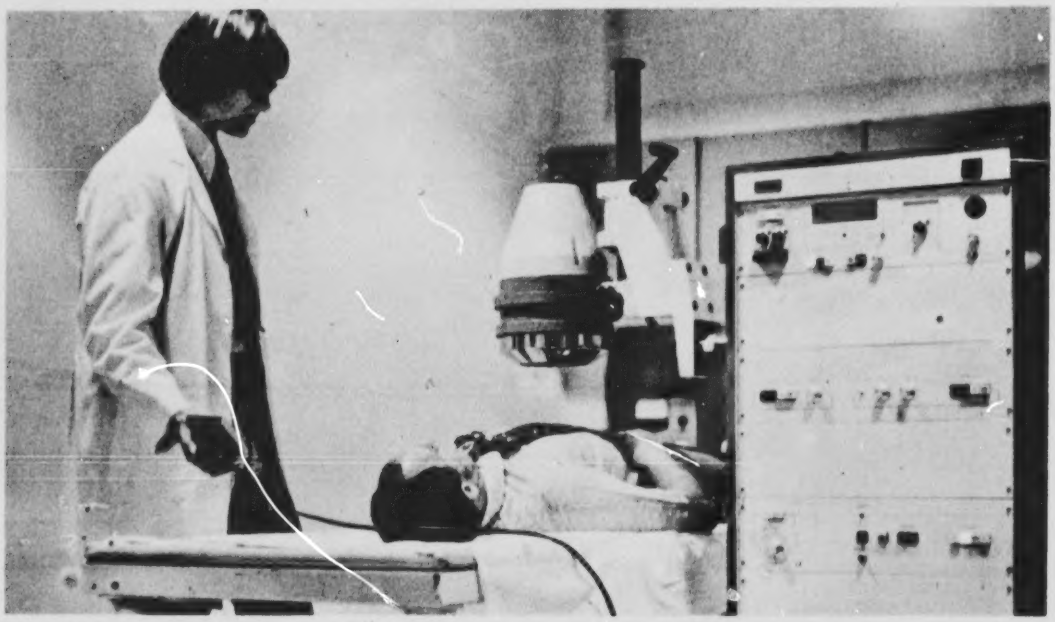
Using a multiple sample counter to speed the counting process for radioimmunoassay studies.



Preparing a patient for a Thyroid uptake study.



Monitoring a dynamic function study using several pieces of equipment.



Positioning the collimator head of a Rectilinear Scanner over a patient.

THE NUCLEAR MEDICINE TECHNOLOGY PROGRAM

Even before World War II, the properties of radioactivity had been explored by scientists and physicians to provide better health care. Atomic research and nuclear developments brought significant advances in nuclear science. One of the results of these explorations in nuclear sciences is nuclear medicine technology.

Nuclear medicine procedures are an outgrowth of techniques developed in hospital radiology, pathology, and internal medicine departments. They are used for both diagnostic and therapeutic purposes. As a diagnostic technique, nuclear medicine technology provides information on organ structure and function that cannot be obtained from radiologic procedures alone. Physicians can examine human organs and observe human metabolism, digestion, and blood flow with increasing precision. While nuclear medicine is most widely used for diagnostic purposes, it has also been found to be highly effective in the treatment of certain types of diseases. For example, thyroid cancer has been successfully treated because therapeutic quantities of a radioactive substance can be concentrated in the thyroid without causing excessive radiation to other tissues.

Nuclear medicine procedures are based on the facts that radioactive drugs can be administered harmlessly to patients, that they localize in a particular organ, and that they therefore enable the organ to be imaged. The radioactive drugs, called radiopharmaceuticals, may be administered by injection, orally, or by inhalation. Depending upon the type of radiopharmaceutical and the method used for administering it, the drug is "taken up" by a particular organ. Sophisticated instrumentation traces where and how the radiopharmaceutical is concentrated in the patient's body.

The use of nuclear medicine procedures has become increasingly widespread and important. In fact, access to nuclear medicine services is now a requirement for hospital accreditation by the American Hospital Association's Joint Commission on Accreditation of Hospitals.

This requirement alone has ensured the expansion of nuclear medicine facilities and a corresponding need for more nuclear medicine technicians. Hospitals in the 100- to 300-bed range are now establishing their own nuclear medicine facilities. Each of these hospitals will need to employ one or two technicians. Furthermore, existing facilities are being expanded, and they are requiring additional support personnel.

These nuclear medicine technicians (NMTs) are needed to assist nuclear medicine physicians by performing a variety of clinical duties involved with nuclear medicine procedures. They prepare and measure the radiopharmaceutical doses for administration to patients and operate specially designed equipment. Furthermore, they are responsible for radiation safety procedures and for maintaining records for the facility. NMTs must also interact with patients. Often they administer the radiopharmaceuticals. NMTs also explain the procedures to the patients, and perform the nuclear medicine tests.

Until a few years ago, technologists in radiology, internal medicine, and pathology departments were trained on the job as they were needed to assist in nuclear medicine procedures. The majority of nuclear medicine technicians or technologists (NMTs) came from radiology departments. The radiologic technologists' knowledge and skill in the areas of radiation safety, manipulation of controls, and patient positioning for imaging enabled them to be trained on the job with little difficulty.

As the need for NMTs grew and their preparation became more comprehensive and complex, on-the-job training grew increasingly less satisfactory. Informal instructional programs varied both in scope and depth. Furthermore many hospitals were not prepared to devote money and time to training programs for NMTs.

A number of organizations became concerned about the preparation of technicians. Responding to that interest and need, the U. S. Office of Education funded the grant under which this document was prepared as part of a pilot development and demonstration project to provide programatic leadership in the field. In July, 1969, the AMA Council on Medical Education approved the "Essentials of an Accredited Educational Program in Nuclear Medicine Technology." The "Essentials" state the minimum standards for an NMT educational program. The Council accredits three types of programs: a baccalaureate degree program; an associate degree program; and a 12-month training program for registered medical technologists, radiologic technologists, or registered nurses. (These "Essentials" can be found in Appendix A.)

The curriculum included in this publication meets the AMA requirements for an accredited associate degree program in nuclear medicine technology. Individuals entering the program do not need previous preparation in an allied health field for entry. The curriculum includes both coursework that is taught at the school and clinical courses which must be taught in a hospital nuclear medicine facility as set out by the AMA Essentials. Graduates will be prepared for employment as entry-level NMTs.

Nuclear Medicine Technicians (NMTs)

Nuclear medicine technicians must have the following special abilities:

1. Scientific Method: The technician should be proficient in the use of a scientific method of inquiry and observation, and in the application of the basic principles, concepts, and laws of physics, chemistry, and the biological sciences pertinent to nuclear medicine technology. In the course of following the directions of the physician to whom he or she is responsible, the nuclear medicine technician must be capable of exercising quality control over his or her work.

2. Facility with Mathematics: The technician must use algebra, geometry, and trigonometry in order to perform the tasks connected with nuclear medicine procedures and instrumentation. Slide rules and desk calculators are everyday tools of an NMT.

3. Equipment Operation: The technician should understand and be able to use the materials and equipment required for the laboratory or clinical work in the nuclear medicine facility. Rectilinear scanners and scintillation cameras as well as detector probes, well counters, and scalers are used regularly in the course of a technician's daily work.

4. Resourcefulness: The technician's degree of competency and depth of understanding should be sufficient to enable the individual to establish effective rapport with patients, physicians, scientists, researchers, and hospital administrators. It requires individual judgment, initiative, and resourcefulness in the use of techniques, procedures, handbook information, and recorded scientific data.

5. Communications Skills: The technician should have the ability to record, analyze, interpret, and transmit facts and ideas orally or in writing with complete objectivity. The individual must be prepared to locate and master new information pertinent to nuclear medicine technology. As nuclear medicine technicians relate to patients who may be very frightened or ill, it is important that they be able to instill in the patient a sense of confidence.

The tasks that an NMT performs falls into five general areas: dose preparation and data handling; patient interaction; equipment operation; radiation safety; and clerical duties.

1. Dose Preparation and Data Handling: The NMT is responsible for the preparation, quality control, and calibration of radiopharmaceuticals that are administered to patients for examinations. After the examination is completed, the NMT organizes the data for the physician's interpretation and examines test results for general credibility. Attention to the details of the procedures and accuracy is essential.

2. Patient Interaction: The NMT positions the patient for the examination and monitors the examination as it proceeds. Nuclear medicine examinations may last as long as two hours. During this time the NMT must be available to reassure the patient and explain the procedure.

3. Equipment Operation: The NMT operates a variety of equipment in performing examinations including cameras, scanners, video tape recorders, and computers. In many cases, the individual also checks the performance levels of the instruments and makes minor repairs. It is important that the picture or scan be taken by following the correct procedures and techniques, or the resulting scan may be undecipherable or open to misinterpretation.

4. Radiation Safety: The NMT is responsible for the use of radioactive materials. Monitoring instruments must be kept in proper operation and personnel exposure to radiation be kept at a minimum. The NMT should be able to handle, store, and dispose of radiopharmaceuticals and clean laboratory ware safely. Monitoring instruments must be used routinely, and a familiarity with regulations and procedures for monitoring and decontaminating personnel and facilities is essential.

5. Clerical Duties: The NMT may be responsible for secretarial work. This includes the scheduling of appointments, typing reports, and keeping records of radionuclide disposition and instrument performance.

Certification of NMTs

Two registries give certifying examinations in the field of nuclear medicine technology. They are the American Registry of Radiologic Technologists (ARRT) and the American Society of Clinical Pathologists, Board of Registry (ASCP). The majority of NMTs are registered by the ARRT. The material covered in this curriculum will prepare an individual to pass the ARRT Registry exam. (Further information about the registries can be found in Appendix B.)

At this time there are NMTs employed who are not certified. However, an increasing number of hospitals are requiring that their technicians be registered by either the ARRT or the ASCP.

Employment Opportunities for NMTs

One of the most essential criteria measuring the success of a technical education program is that employers compete for graduates of the program. The best-prepared technicians will not find employment, however, if the field is already glutted with qualified personnel. This is certainly not the case in nuclear medicine technology. According to TERC's Interim #1 Report, Survey of Job Characteristics, Manpower Needs, and Training Resources (1969) there are approximately 4,500 NMTs in the United States and approximately 1,300 new NMTs will be needed each year. The need for education programs providing high caliber preparation is growing and the graduates of such programs are ever more greatly in demand.

RESOURCES REQUIRED

It is important that the program planner consider those resources necessary for an NMT program. These include the clinical experience in a nuclear medicine facility and the resources for the technical specialty courses of the curriculum unique to nuclear medicine technology. A college providing allied health programs in other areas will already have some of the necessary resources. These include faculty, laboratories, and courses. However, a college considering an NMT program must be prepared to make a substantial capital investment. A program coordinator must be hired a year in advance to plan the program. Furthermore, the NMT equipment makes this program one of the most expensive in a community college.

Clinical Affiliations

A school considering the establishment of an NMT program must be certain that adequate clinical experience can be provided to the student. This is of primary importance for several reasons. Clinical affiliation with a nuclear medicine facility is a requirement for an accredited NMT program. (See Appendix A.) Much of the nuclear medicine equipment is too expensive for a school to purchase for its laboratories. Furthermore, a school laboratory could not simulate the experience a student would gain through contact with patients and hospital personnel. This experience is so important that the student will spend half of the total contact hours in supervised clinical practice in a nuclear medicine facility.

A program that graduates fifteen to twenty students should have access to nuclear medicine facilities in three to ten hospitals. The exact number of hospitals will depend upon the size of the program and the number of students each hospital can accommodate. A large teaching hospital may have sufficient staff and space to provide experience for as many as ten students. A smaller hospital, however, may find three students a strain on its resources. Individual attention for students is an important component. Therefore, the number of students at each hospital should also be determined by the availability of qualified instructors.

When establishing a new NMT program it is a good idea to approach hospitals conducting their own NMT programs as well as those not currently doing so. These hospitals may welcome the opportunity of sharing the responsibility of preparing NMTs with local community colleges and technical institutes.

It is important that clinical placements be established in locations that are geographically convenient to the school. The number of hospitals having comprehensive nuclear medicine facilities is increasing. However, in 1974, only metropolitan areas with populations of approximately one million support enough hospitals with the necessary facilities for preparing fifteen to twenty students per year. Class scheduling may require the student to return to the college campus for classes on the same day as the clinical practicum. The school and hospital should therefore be no more than one-half hour traveling distance apart.

The clinical experience is to provide the students with a comprehensive and varied experience. Therefore, clinical affiliates should be only those hospitals with modern facilities. Rotation through more than one clinical affiliate may provide the student with clinical experience not available at just one hospital. The experience of established programs indicates that a two- or three-month time period provides for an optimum learning experience.

When a hospital agrees to become an affiliate of the school, a contractual agreement should be made. Many hospitals will accept the standard agreement that applies to clinical experience for other allied health students. (Appendix C contains a sample contract.) The school administrator may want to check with the legal counsel of the school and the hospital regarding possible modification of this agreement.

The Technical Specialty Courses

The technical specialty courses of an NMT program consist of the ten courses listed in Table I. Three of these courses--Clinical Practicum I, II, and III--will be taught entirely at the hospital by clinical instructors. In addition, the laboratory section of Nuclear Instrumentation II may also be taught at the hospital. The other seven courses will be taught at the college. With the possible exception of Nuclear Instrumentation II, the laboratory instruction will ideally take place at the college.

There are thirty-one class hours per week of technical specialty courses taught at the college. Assuming that instructors will teach approximately fifteen hours per week, the college should be prepared to have two additional instructors for these courses.

Table I. The Technical Specialty Courses

NMT Courses	Class Hours	Lab Hours School	Lab Hours Hospital
Introduction to NMT & Hospital Orientation	2	3	
Radiation Physics	3		
Nuclear Instrumentation I	3	3	
Nuclear Instrumentation II			3
Clinical Practicum I			14
Clinical Practicum II			20
Clinical Practicum III			40
Fundamentals of Radiochemistry & Radiopharmaceuticals	3	3	
Clinical NMT I	3	2	
Clinical NMT II	3		

Available Allied Health Courses

A school that is already providing programs in Radiation Therapy Technology or Radiologic Technology may not require new faculty or laboratories for the courses listed in Table II. By sharing courses with these other programs, effective use can be made of faculty, equipment, and space. The faculty who teach shared courses should have enough knowledge of the specifics of nuclear medicine technology to provide examples of relevance to NMT students.

Table II. Available Allied Health Courses

ALLIED HEALTH COURSES (NMT, RT, RTT)

- Anatomy, Physiology & Pathology I
- Anatomy, Physiology & Pathology II
- Applied Mathematics
- Chemistry for the Health Sciences
- Radiation Safety & Radiation Biology
- Medical Terminology
- Social Psychology for the Health Sciences

It should be mentioned that the two general courses of the curriculum--Communications Skills and Technical Reporting--can be taught in existing courses by existing faculty.

Capital Requirements

A year of planning should be estimated for establishing a well-run program. A program coordinator should therefore be hired a year before the new program becomes operational. This person will be the school's program representative and will work with the physician director responsible for the program. During this planning time, equipment can be acquired and qualified faculty hired. It is also essential for the planning and coordination of the clinical experience.

The equipment required for an NMT program causes this program to be one of the most expensive programs in a community college. Laboratories alone will cost about $150,000. It is therefore important that the program planner be certain that the school is able and willing to make the capital investment for a program of this kind. In some instances affiliation with a college or university that offers a program such as Medical Physics may result in sharing equipment and space, thus reducing the total program cost.

LOCAL NEEDS AND RESOURCES SURVEY

The growing need for NMTs has been substantiated. Nevertheless it is important that a school considering an NMT program determine how effectively its proposed program will serve this need.

First, the geographical area to be served by the program should be defined. Traditionally, two-year postsecondary occupational programs serve a limited geographical area. In establishing a program for nuclear medicine technology, however, the school may be serving a larger area that it does with programs for established occupations. A community college that is part of a state system may therefore wish to obtain an agreement with the state educational authorities broadening the geographical area it serves.

Second, the administrator should ascertain what local resources providing education of NMTs already exist. Hospitals within the area may already be providing on-the-job training or a one-year certificate level program. Also, private institutions may be providing short-term courses. The effects of these resources on a newly formed NMT program should be taken into consideration.

Current trends in nuclear medicine technology are towards more formal education. Therefore, existing programs may by no means be detrimental to the establishment of an associate degree NMT program. NMT hospital programs may welcome the opportunity to affiliate with a local educational institution. A listing of formal NMT preparation programs in the United States may be found in the TERC Digest of Educational Programs: Nuclear Medicine Technology (1974 Update). The American Medical Association Council on Medical Education also publishes a list of accredited programs. A visit to schools and hospitals having NMT programs can provide valuable information. Case studies conducted by TERC of existing NMT programs are also available. They describe the process of establishing these programs.

Third, it should be determined whether there are enough hospitals with NMT facilities willing to provide clinical experience. Hospitals having nuclear medicine facilities and their bed capacity are indicated in the current American Hospital Association Guide to the Health Care Field.

A direct canvass of hospitals can be made through a mailed questionnaire. A cover letter from the school administrator should indicate that the questionnaire is solely for the purpose of deciding whether to initiate an NMT program. A short questionnaire containing only essential questions in unambiguous terms is most likely to be completed. An addressed stamped envelope also contributes to a high response rate.

The questionnaire should be directed to the person within the hospital most likely to know about future NMT employment possibilities. The physician in charge of the nuclear medicine facility or the chief technologist will have more direct knowledge than the hospital's personnel department.

Responses to questions asked in the mailed survey should include:

- number and titles of present nuclear medicine staff
- anticipated expansion of nuclear medicine facility and staff
- opportunities for promotion
- pay scale for entry-level employment
- types and numbers of diagnostic procedures performed
- type and quantity of major instrumentation
- present training program for nuclear medicine technicians
- interest in discussing affiliation with community college.

A person familiar with the job responsibilities that a nuclear medicine technician performs should assist in designing the survey questionnaire. This advice can eliminate unnecessary questions and ambiguous terms. (A sample questionnaire is in Appendix D.)

In considering the survey results obtained from the hospitals, the administrator should realize that the present state of the economy will influence responses. Employers may be overly optimistic about future jobs at the time of an expanding economy or unduly pessimistic during a declining economy.

Many programs are conceived by an informal ad hoc committee of hospital personnel and educators concerned with nuclear medicine technology. The advice of an ad hoc committee can help to achieve an accurate, realistic determination of the job market for graduates of an NMT program. This committee can assess the need for a program with assistance from the results of the survey. The ad hoc committee would also be useful in soliciting support for the program. Some of the members of this informal committee might become part of the formal Program Advisory Committee discussed in the next section.

PROGRAM ADVISORY COMMITTEE

After the decision is made to establish an NMT program, a formal advisory committee should be appointed. Selection of the committee members deserves careful attention, since their active participation will be a major factor in carrying out a successful program.

The AMA requires that the program director be a physician qualified in the clinical use of radionuclides. It is suggested that the physician director of the program chair the advisory committee. Experience has shown that the physician director's cooperation and guidance are essential to planning the program and implementing its first year. Since effective functioning of the Program Advisory Committee is particularly crucial at this point, this individual should be capable of establishing strong working ties with the school and the other clinical affiliates.

Among groups to be considered for representation on an NMT Program Advisory Committee are:

- College staff members
    - The NMT program coordinator
    - Faculty who will teach NMT students
    - Guidance counselors
- Practicing professionals
    - The physician director (committee chairperson)
    - Other physicians whose practice or research involves nuclear medical procedures
    - Nuclear medicine technicians or technologists currently employed locally
    - Medical physicists, radiation protection personnel, and allied health professionals whose work involves extensive use of radionuclides
    - Officers of local professional society chapters (Appendix E)
- Hospital administrators
- A student representative

While the reason for including most of these categories is clear, some categories deserve further emphasis.

Participation by college faculty members during the first planning phases will strengthen their commitment to the program. The exchange of ideas between those responsible for implementing a program and those giving advice about its operation can provide a realistic base for effective training.

Practicing professionals can advise the committee about the relevance of curriculum content to the tasks of the technician. They can also inform the faculty about developments in nuclear medicine instrumentation which would require curriculum modification and addition of continuing education courses for employed NMTs.

The participation of practicing technicians will provide the background necessary for graduating students with up-to-date knowledge and skills. Some of these technicians and technologists on the advisory committee will eventually be clinical instructors at the hospital affiliates. Many of them will have previous experience training on-the-job NMTs. Fewer will have formal background as educators. It is therefore important that they be represented on the committee to add their knowledge in training NMTs and to learn the expectations of the program.

Hospital administrators should be represented on the advisory committee. They serve two important functions: they can help arrange for students' clinical training, and they may be able to help students secure employment upon graduation.

After an NMT program is underway, a representative from the student body should be invited to join the committee.

During the planning stages of the NMT program, the advisory committee can assist in:

- giving advice on curriculum content, faculty requirements, and laboratory facilities and equipment;
- enlisting knowledgeable consultants and faculty members; and
- making arrangements with local hospitals to ensure that students will have the necessary clinical instruction and experience.

Once the program is implemented, the advisory committee can assist in:

- placing graduates in jobs,
- evaluating the performance of program graduates as employees,
- modifying the program to meet local needs of employers and students according to performance evaluations,
- modifying the program to keep it timely according to technological advances,

- providing continuing education for employed NMTs to upgrade their skills and technical knowledge, and

- serving as a link with the community in which the program is located.

The length of an advisory committee member's term will vary. Some members may have more to contribute to program planning and the early decision-making phases. Their term might end after one year. They can be replaced by people whose experience would be more valuable to the committee after the program has been established. Continuity can be maintained by having overlapping terms. Experienced committee members can work with new appointees.

Advisory committees usually range in size from six to twenty members. Twelve is considered a very workable number.

Members serve without pay and are usually involved with other activities. Their time is therefore best utilized by inviting them to meetings which are called to discuss specific tasks or problems. When general meetings are called, an agenda should be carefully planned in advance.

FACULTY

The faculty is a major factor governing the success of an educational program for technicians. College faculty members should be able to coordinate their efforts with each other and with hospital clinical instructors. The faculty must be enthusiastic about the process of technical education and believe in the goals of their particular education and believe in the goals of their particular institution. Since the field of nuclear medicine technology is still developing, the most effective faculty members will have a keen desire to keep up with changes in the field. New equipment and procedures will affect on-the-job responsibilities of program graduates. Instructors should be creative in modifying both course content and teaching methods as these scientific advances occur. Because the graduate NMT plays a unique role in the hospital, the nuclear medicine technology faculty must be concerned with the effect of interpersonal relationships on job performance. This concern should be incorporated into their teaching techniques and curriculum.

The Physician Director

The AMA Council on Medical Education requires that "...the director be a physician qualified in the clinical use of radionuclides." The physician director is usually based at one of the affiliating hospitals. He/she is responsible for the entire program and is primarily responsible for the quality of clinical training. This means that he/she has responsibility for the clinical instructors in hospitals other than his/her own. This is a potentially confusing situation that must be handled with some care.

As chairperson of the program advisory committee, the physician director will be in touch with all the members of the committee. Through this committee he/she can help initiate a tone of good will and cooperation in the program.

The NMT Program Coordinator

Although the physician director has the ultimate authority concerning this program, the NMT program coordinator is often the key to a well-functioning program.

The program coordinator has several areas of responsibility. When the program is in the initial planning stages, he/she will serve on the program advisory committee. This individual will develop the details of the initial curriculum and modify course content as necessary. Acquisition of equipment is the responsibility of the program coordinator.

Once the program is established the program coordinator assumes new duties. He/she is responsible for student recruitment and graduate placement. Some of the technical specialty courses are taught by the program coordinator. A large part of the program coordinator's time is spent visiting the hospital affiliations to ensure that they are providing the students with adequate and comprehensive experience.

The position calls for the statesmanlike qualities of coolheadedness and objectivity. The program coordinator negotiates between the college and the hospitals regularly. This individual must be able to communicate well with both the faculty at the college and the clinical instructors at the hospitals. The priorities of all the institutions involved and the students are a constant concern.

The qualifications of an NMT program coordinator include a B.S. degree in nuclear medicine technology and certification by an appropriate professional registering body. (See Appendix B for registering bodies.) Preferably the person will have had two years' experience working in the hospital setting. This would provide the experience necessary to understand the problems of students in a new setting and of the NMT clinical instructors encountering students. Technical and administrative competence are naturally prerequisites.

Recruitment of Faculty

The AMA Council on Medical Education requires that "...the teaching staff should include qualified instructors in Radiation Physics and Radiation Biology adequate for both group and individual instruction. It should also include at least one instructor who is a registered nuclear medicine technologist and who is actively engaged in nuclear medicine technology."

Schools offering a B.S. degree in nuclear medicine technology are a source of recruitment for a person who is a registered nuclear medicine technologist. The Digest of Educational Programs: Nuclear Medicine Technology, TERC, 1975 lists schools that are preparing qualified candidates.

Staff members of the affiliated hospitals may serve as part time faculty at the school to teach Radiation Physics, Radiation Safety and Radiation Biology and Fundamentals of Radiochemistry and Radiopharmaceuticals. If the school has a radiologic technology program, faculty with competency in most of these areas are usually available.

Clinical instructors may also be employed as part-time faculty to teach Clinical Nuclear Medicine Technology or Nuclear Instrumentation. Another faculty source is staff physicists or physicians serving a residency in nuclear medicine. Care must be taken, however, that these people are capable of taking a real interest in the education of nuclear medicine technicians.

Teaching Load

It should be remembered that in addition to clinical instructors at the hospital, the college should expect to have the equivalent of two full-time instructors. This assumes that no faculty person has a teaching load of more than fifteen hours per week.

Once the program is well-established, the program coordinator may be able to teach up to ten hours per week. The first two or three years of the program will require a great deal of attention from the program coordinator. Therefore, it is recommended that this person teach no more than six hours the first two years.

Additional Considerations

The chief administrator can assist the faculty in the following ways:

> Released time for short continuing education courses, longer-term studies in basic science, and periods of work experience should be allowed.
>
> Hospital and school instructional staff meetings should be scheduled regularly. The purpose of the meetings will be to coordinate coursework with clinical work, to present successful - or unsuccessful - teaching techniques and laboratory procedures and to discuss new developments in the field through presentation of current journal articles. The learning center/library staff should be included in these meetings so that optimal use may be made of this facility.

Faculty assistance should be provided for routine tasks such as setting up laboratory experiments.

Faculty membership in professional societies should be encouraged. This participation will provide opportunities for continuing education of faculty.

ORGANIZATION BETWEEN THE SCHOOL AND HOSPITALS

The initial establishment of a cooperative spirit between the educational institution and the affiliated hospitals is crucial to the success of an NMT program. Unresolved conflicts and uncompromising attitudes between the institutions will most certainly lead to unsatisfactory preparation of students if not to the collapse of the program. Representatives of all the cooperating institutions must have a common understanding of their responsibility to the program.

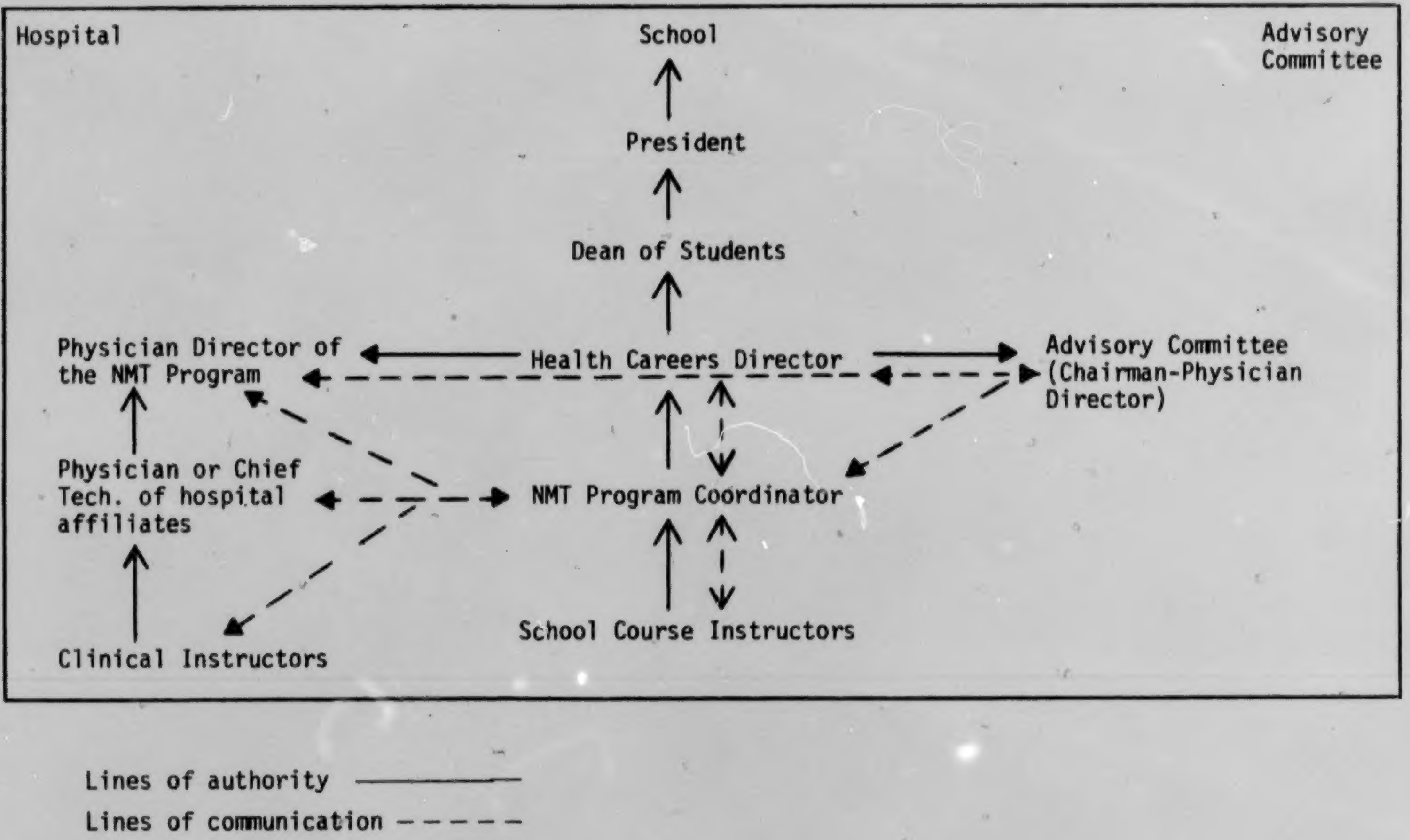
This common understanding can be achieved if all the participants meet in a formal session at the outset. A written plan should discuss the following points:

- The educational goals of the program
- The proposed size of the clinical placements, number of students per clinical instructor, and the schedule for student placement
- Skills students should acquire before beginning their clinical placements
- Skills students will learn during clinical placements
- Coordination between coursework and clinical work
- The respective responsibility of school and hospitals for supervision and liaison of students and faculty.

The planning and implementation of an NMT program involves many individuals from several institutions. Misunderstandings that could jeopardize the necessary cooperative spirit must be avoided. Therefore, the lines of authority and levels of responsibility should be established at the outset. A plan that is agreed upon by all participating institutions will serve to enhance direct communication and increase cooperation.

A model for the organization of an affiliated program in nuclear medicine technology is suggested in Table III on the following page. The lines of authority at the school are quite clear. At the head of the hierarchy is the President of the College, followed by the Dean of Faculty, the Chief of Health Career Programs, the NMT Program Coordinator, and the course instructors in descending order. All these participants are employed by the college.

Figure 5. Organizational Model of an NMT Program


Hospital
School
Advisory Committee
President
Dean of Students
Physician Director of the NMT Program
Health Careers Director
Advisory Committee (Chairman-Physician Director)
Physician or Chief Tech. of hospital affiliates
NMT Program Coordinator
School Course Instructors
Clinical Instructors
Lines of authority
Lines of communication

The lines of authority concerning the hospital personnel are more complicated. The physician director has responsibility for the entire program. This includes responsibility for the quality of clinical instruction at all the affiliated hospitals and responsibility for clinical instructors of institutions other than his or her own. These instructors will naturally have loyalties to their own institution. This potentially confusing situation can be solved by the careful delineation of authority at the beginning of the program and by providing accessible meditation for problems.

The physician director has the ultimate authority concerning the program. However, the individual through whom the lines of communication will run is the NMT Program Coordinator. Once the initial problem areas of a newly established program have been identified and suggestions have been made for solving them, much of the day-to-day responsibility will fall to this individual. The program coordinator is in the key position for negotiating between the school and the hospitals and should be able to arbitrate decisions which reflect the priorities of all the institutions concerned as well as of the students.

LABORATORY EQUIPMENT AND FACILITIES

The laboratory sessions in technology programs are designed to reinforce theory with basic application. In a health-care technology such as nuclear medicine, modern laboratory facilities and equipment are critical to the learning process of the students.

Ideally, facilities for basic sciences and nuclear medicine course laboratory sessions would all be located on the college campus. However, equipment for most of the NMT specialty courses are generally located only within the hospital NMT department. This equipment is too expensive for most community colleges, technical institutes, and divisions of four-year schools.

Laboratories should be equipped at the school for Fundamentals of Radiation Chemistry and Radiopharmaceuticals and Nuclear Instrumentation I. Hospitals or equipment manufacturers may be willing to donate used instrumentation for campus laboratories.

Laboratory training costs can also be minimized by staggering laboratory time so that the equipment is utilized efficiently. Special care must be taken with scheduling if this arrangement is used.

Consultation with the laboratory instructor prior to selection of equipment is important since the instructor can determine what equipment is required. He or she can also decide what used equipment can be adapted for teaching purposes and if this is cost-effective.

LEARNING RESOURCE CENTER

A properly equipped learning resource center provides several services to a technology student. Regular class and laboratory texts can be supplemented with references that treat a subject in greater depth. If the school library does not have a requested volume, it may be secured through interlibrary loan. Also, the center provides opportunities for strengthening skills in reading, studying, basic science, and mathematics. Appropriate equipment, programed texts, and trained staff contribute to the success of developmental learning programs.

Keeping up-to-date is important in nuclear medicine technology. Job tasks will change frequently as new equipment and procedures are introduced into the hospital. The technician should be familiar with the published materials that discuss developments in this changing field. Assignments requiring library use will ensure that the students use the center.

Teaching staff can cooperate with library staff in selecting new materials and removing obsolete references. Choosing the trade and technical journals with the newest scientific data in nuclear medicine technology is important. The library staff may be especially helpful to NMT faculty by securing instrumentation and radiopharmaceuticals catalogs. The NMT students must have equal access to materials used in other allied health or medical programs.

While the student may depend on the center primarily for technical materials, the facility can also encourage the student's broader humanistic interests and understanding.

STUDENT RECRUITMENT, SELECTION, AND SERVICES

Student recruitment is particularly important during the year prior to the introduction of a new program. The recruitment efforts are the responsibility of the program coordinator with the help of the college's information office and administrative staff. The program advisory committee members can be especially helpful with recruitment. They can arrange for the program staff to give talks about the proposed new program to local civic groups. In fact, many of the members may be willing to make presentations themselves.

Many civic groups are particularly interested in the allied health field. For instance, auxiliaries to state and local medical societies sponsor health fairs as well as other recruitment activities in this field. Speakers should be chosen with care and be well-prepared for their presentations.

Potential students may be informed of the forthcoming NMT program in several ways. Local newspapers, radio, and television stations will welcome news releases announcing the new program. High school guidance counselors can be informed of the program through information sheets and visits from college staff. They can also be invited to inspect the college campus. High school math and science faculty would also be interested in brochures such as those available from TERC and the Society of Nuclear Medicine. The local Veterans Administration Officers should be provided with information for veterans.

If the students of the NMT program are successfully placed in jobs, future student recruitment will require less effort. News releases about graduates serve to keep the public aware of the program's success.

It is a disservice to potential students, to faculty, and to the college to admit students whose preparation and qualifications do not ensure successful completion of the program. For purposes of morale and of cost-effectiveness, a high drop-out rate should be avoided.

Student selection can be based on four major factors: age, high school or military work record, screening tests, and a personal interview. Before students begin their work with radionuclides in an NMT program, they must by law be at least 18 years old.

For applicants entering a program without previous allied health experience, secondary school background should consist of at least two years of mathematics, including algebra, and geometry. One science course with laboratory is mandatory and three; biology, physics, and chemistry, are preferred. Introductory courses in allied health are helpful, but not essential. The student's high school record may also contain comments which indicate an interest in a postsecondary technology course.

Tests of scholastic ability are available in standardized form. Some program directors have developed special tests for the mathematical aptitude and elementary algebra ability of potential NMTs. For the person who is not a high school graduate, passing a standard equivalency test is acceptable.

Students who have begun in another allied health field may wish to transfer into nuclear medicine technology. These students should be given credit for the relevant previous coursework.

Because NMTs were traditionally trained in hospitals, many do not have a postsecondary degree. Consideration should be given to evaluating their experience to determine their eligibility for advanced standing in an NMT program.

A personal interview is an important part of the application process. The future NMT must be able to communicate with people on all levels in the hospital. The interview may also be influential in guiding a student whose real interests and aptitudes lie elsewhere.

Several services should be made available to students including financial assistance, health care, remedial support, and guidance counseling.

Remedial help in study skills, reading, communications, mathematics, and/or science may be essential for some students. The learning resource center can provide programed teaching aids in all these fields. A summer or evening program may be made available for remedial work in combination with a reduced load and lengthened study term. Some colleges provide a pretechnical year for students who lack the appropriate background.

A guidance counselor familiar with the technology can serve as a liaison between students and faculty. If a student's performance is not meeting expectations, the counselor can steer him or her into remedial work, or, if necessary, into a different program. The guidance counselor's efforts can be particularly beneficial if a student encounters difficulty with interpersonal relations in the clinical work experience.

Field trips to hospitals are important for NMT students. They give students exposure to the hospital setting before they begin their clinical practicum. In addition, representatives of nearby hospitals, radiopharmaceutical companies, and NMT equipment manufacturers should be encouraged to give lectures or conduct seminars.

Job counseling should be available. Students must be made aware that relocation after graduation might be necessary. There will not necessarily be job openings in the areas where the school is located. Since one indication of the success of a new program is the number of graduates placed in jobs, employment consideration of graduates should be given serious attention.

THE CURRICULUM

Nuclear Medicine Technology Curriculum Outline

FIRST SEMESTER	CLASS HOURS	LAB HOURS	OUT-SIDE STUDY	TOTAL HOURS
Introduction to NMT & Hospital Orientation	2	3	4	9
Radiation Physics	3	0	6	9
Applied Mathematics	3	0	6	9
Anatomy, Physiology & Pathology I	3	2	6	11
Communications Skills	3	0	6	9
TOTAL	14	5	28	47
SECOND SEMESTER				
Radiation Safety & Radiation Biology	3	0	6	9
Nuclear Instrumentation I	3	3	6	12
Anatomy, Physiology & Pathology II	3	2	6	11
Chemistry for the Health Sciences	3	3	6	12
Medical Terminology	2	0	4	6
TOTAL	14	8	28	50

SUMMER

1. Studies to meet special requirements of state or institution, if necessary.
2. Optional clinical practicum of 10-12 weeks in hospitals.
3. Remedial work, if necessary.
4. 2 week hospital concentration.
5. Summer work for those entering in second year.

THIRD SEMESTER				
Nuclear Instrumentation II	3	3	6	12
Clinical Practicum I	0	14	0	14
Clinical Nuclear Medicine Technology I	3	2	6	11
Fundamentals of Radiochemistry & Radiopharmaceuticals	3	3	6	12
TOTAL	9	22	18	49
FOURTH SEMESTER				
Social Psychology for the Health Sciences	3	0	6	9
Clinical Practicum II	0	20	0	20
Clinical Nuclear Medicine Technology II	3	0	6	9
Technical Reporting	3	0	6	9
TOTAL	9	20	18	47
SUMMER				
Clinical Practicum III (12 weeks)	0	40	9	40

Brief Description of Courses

FIRST SEMESTER

Introduction to Nuclear Medicine Technology and Hospital Orientation

Hospital organization is presented as well as the relationship of nuclear medicine services to other hospital services. Student observations in affiliated hospitals are correlated with lectures on NMT, hospital ethics, patient care, and emergency procedures.

Radiation Physics

The concept of energy and its application to the atom and nucleus is introduced. Radioactive decay, the common radiation units, and the interaction of radiation and matter are stressed.

Applied Mathematics

A review is made of arithmetic, algebra, basic trigonometry functions, logarithms, and graphing. Examples are provided for course relevance to NMTs.

Anatomy, Physiology & Pathology I

A detailed study of the structure and function of the normal human body at the microscopic (cell) level and gross (organ) level is presented. This course also introduces pathological conditions the diagnosis of which may require services of the nuclear medicine facility.

Communications Skills

This course is designed to improve the student's listening, reading, conversational, and writing skills and to assist him in the development of language power.

SECOND SEMESTER

Radiation Safety & Radiation Biology

The guideline regulations for radiation safety in terms of the units of exposure are explained, and the student will be familiarized with instruments and devices which monitor radiation levels. Techniques for safe handling of radioactive material is emphasized. Elements of radiation biology include interaction of radiation with the cell genetic damage, and delayed effects such as carcinogenesis.

Nuclear Instrumentation I

The first semester of this two-semester course parallels Radiation Safety and Radiation Biology with a discussion of instruments used for radiation surveys and personnel monitoring. Radiation safety principles are demonstrated in the laboratory. A study of the components of scintillation detectors and the theory of counting statistics conclude the course.

Anatomy, Physiology & Pathology II

This course covers the respiratory, excretory, digestive, and circulatory systems in lectures, demonstrations, and labs. It concludes with an introduction to immunology.

Chemistry for the Health Sciences

This course includes the basic theories of inorganic chemistry, organic chemistry, and biochemistry. In the laboratory the student learns to operate a pH meter, centrifuge, balance, filtering flasks, and to use the various pipets.

Medical Terminology

The student's vocabulary of medical terms, including the meaning of the common prefixes and suffixes, is developed.

THIRD SEMESTER

Nuclear Instrumentation II

This course is a continuation of Nuclear Instrumentation I. The use of imaging systems, including the principles of their operation are emphasized. Laboratory exercises for this course will generally take place at affiliated hospitals because of the costly equipment involved.

Clinical Practicum I

Observation of nuclear medicine technician duties at one or more hospitals is provided for the student.

Clinical Nuclear Medicine Technology I

This course reviews the concepts of anatomy, physiology, pathology, and radiopharmaceuticals as they relate to the various clinical nuclear medicine procedures. Laboratory exercises are designed to reinforce these concepts.

Fundamentals of Radiochemistry and Radiopharmaceuticals

The student is introduced to fundamental chemistry concepts, generator systems for obtaining radionuclides, and the quality control techniques for validating test results.

FOURTH SEMESTER

Social Psychology for the Health Sciences

A study of psychological principles that will be of assistance in the understanding of interpersonal relations are presented. Motivation, emotion, perception, and learning are among topics considered with reference to effective individual and group behavior.

Clinical Practicum II

Nuclear medicine technician duties are practiced by students under close supervision at one or two hospitals.

Clinical Nuclear Medicine Technology II

This is the second part of a two-semester course. The practical details of the various commonly performed procedures in nuclear medicine are presented including imaging (both static and dynamic and *in vitro* tests.

Technical Reporting

The literature of nuclear medicine technology is introduced through library research projects forming the basis for oral and written reports.

SECOND SUMMER (12 weeks)

Clinical Practicum III

Student practice of nuclear medicine technician duties under limited supervision at a hospital.

Curriculum Content and Relationships

Functional competence in a field such as nuclear medicine technology has at least three components around which the curriculum must be designed:

1. The training should prepare the graduate to be a productive employee in an entry-level job.

2. The broad technical training, together with a reasonable amount of experience should enable the graduate to advance to positions of increasing responsibility.

3. The foundations provided by the training must be broad enough so that the graduate can do further study within his field. This further study may consist in the reading of journals, new text materials, or enrolling in formal courses. A two-year technology program has certain unique requirements that influence the content and organization of the curriculum. First, information is concentrated in a short period of time. Second, part of the program takes place in a hospital. This nuclear medicine technology curriculum guide reflects three basic requirements: functional utility, units of instruction in specialized technical subjects, and provision for the teaching of principles by application.

The sequence of courses in a two-year technical curriculum is as important as the content of the courses. The limited time available must be used to full effectiveness. The subject matter in the curriculum is coordinated to blend smoothly from one group of courses into the next. The student is carried to a deeper understanding of basic principles, while understanding of the different areas of nuclear medicine technology is broadened. This is in sharp contrast to professional curriculums in which basic and somewhat unrelated courses make up the first part of the study program and specialization is deferred to subsequent terms.

The relationship between the laboratory and class lecture or theoretical study is of great importance in a technical education curriculum. All of the theory, skills, techniques, applied principles, materials, knowledge, processes, and understanding needed by the technician could be taught in the laboratory without separate and organized theoretical classes. The converse is not true. Technician's laboratory experience, skills, know-how and capability cannot be learned in classrooms without laboratories. However, organized and related ideas, concepts, and factual information can be taught in "theory" classes. Judiciously using demonstrations and visual aids, employing selected texts and references, and requiring regular and systematic outside study on the part of the student are important aids. Group teaching usually makes more efficient use of the instructor's time in a "theory" class than in a laboratory. These classes tend to emphasize and develop the student's skill in obtaining knowledge from printed sources. Coordination between the amount of the scientific and technical specialty taught in the "theory" class and that taught in the laboratory is crucial.

This curriculum provides some part of the time for laboratory hours in the technical specialty during the first two semesters, because introductory and elementary laboratory skills and knowledge of apparatus, tools, processes, materials, devices, and good practice can (and should) be learned in the laboratory as early as possible and in some cases can be started without much underlying theory.

Since many basic laboratory skills and enough basic theory have been learned in the first year, relatively less time is required to illustrate basic principles in second-year courses. During the second year, more technical specialty courses are studied, the total hours of laboratory time are greater than in the first year, and more time is spent participating in hospital procedures. Experience has shown that the relative number of semester hours required for science or technical specialty laboratory work, compared to class theory hours, should not be reduced. A reduction of laboratory work usually causes the student to lose interest and fail, or to abandon the course: it can also produce a graduate who is deficient in the essential laboratory capabilities and is unemployable at the technician level.

In technical curriculums it is especially important that specialized technical course work be introduced in the first semester. Deferring this introduction even for one term imposes serious limitations on the effectiveness of the total curriculum. Several important advantages occur from an early introduction of the technical specialty:

1. It provides motivation. If the first semester consists entirely of general subjects--mathematics, English, general science, and social studies--technical students often lose interest. Since nuclear medicine technology takes place in the hospital it is important that the student be introduced to this setting at the beginning of the program to help confirm his desire to be a part of such an environment.

2. The introduction of the technical specialty in the first semester makes it possible for the student to achieve great depth of understanding in specialized subjects in the later stages of the two-year program.

3. The student sees immediate application of the principles he studies in the basic science and related mathematics courses which he is studying concurrently.

The technician's work often involves potential dangers that require the use of precise procedures. The procedures are combined with an understanding of the equipment he or she uses and meticulous observance of safety practices necessary for handling radioactive materials. Safety is a constant preoccupation in this field, and its practice must be emphasized continually from the beginning of the course.

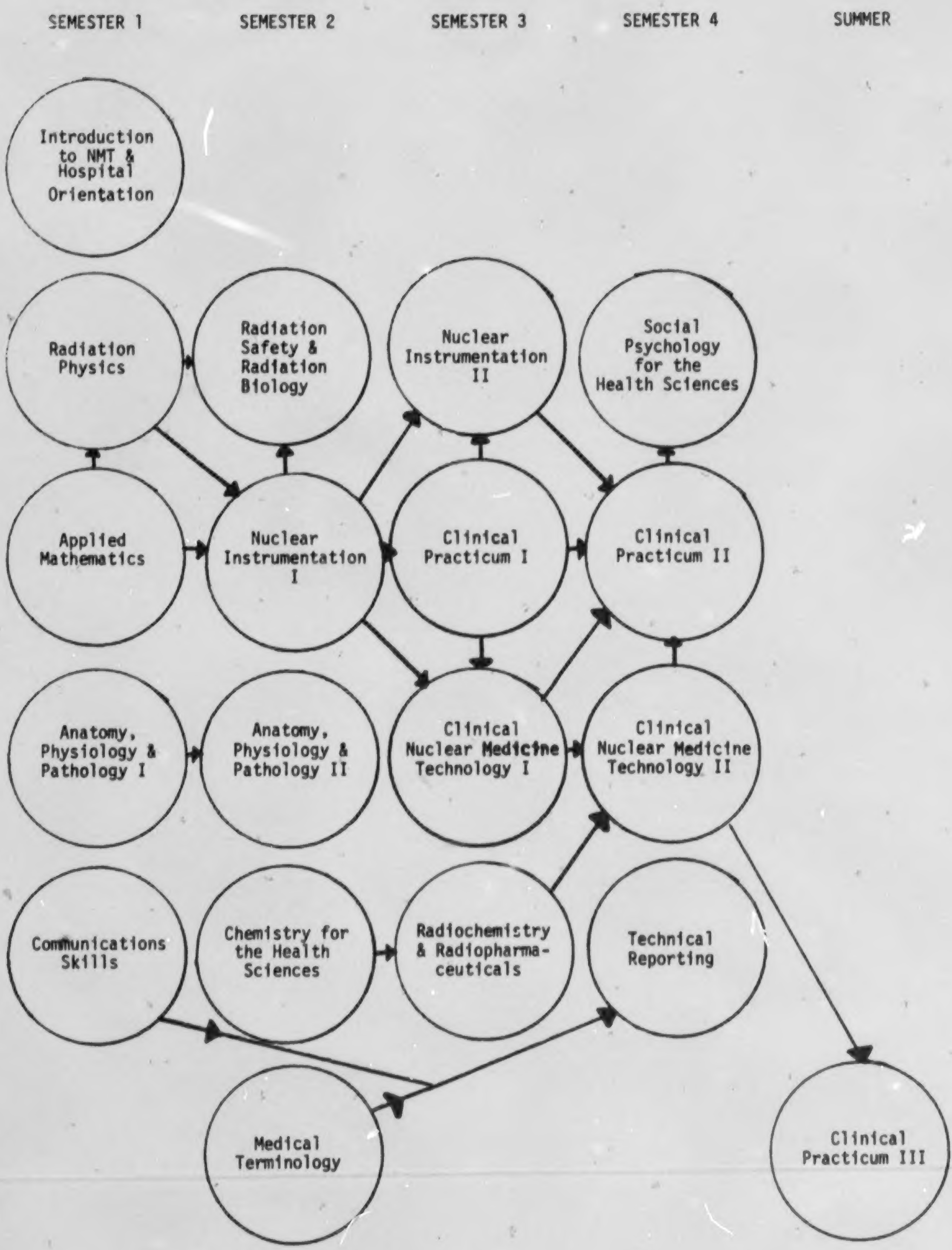
Honesty and integrity must be stressed in the training of any technician. Observations made must be reported accurately, and modification in data should be fully explained in the records. False reporting should be dealt with instantly by the instructor. The original data recorded by an employed technician may become evidence in a court of law and are therefore of great importance.

The Student's observations will be reocrded in a laboratory log book. The laboratory log book is a bound, journal-type notebook with numbered pages in which the student is required to make a permanent record of each laboratory experiment, and its objectives, all pertinent drawing, equipment lists, observed and computed data, date of experiment and name of observer. A similar type of journal recording is required of most employed technicians. The laboratory log is recommended for use during the final semester of the program and should constitute a complete chronological record of a student's technical course work for that semester.

In addition to competent technical skills, the nuclear medicine technician must possess good communications skills and a strong sense of responsibility. During the course of the day, the NMTs will be expected to articulate work results to other technicians and physicians. They will have to deal with people who are ill and frightened; and most importantly, they will have the direct or indirect responsibility for the well-being of other human beings.

The curriculum is designed to enable the student to meet his technical responsibilities and develop the necessary personal attributes to be effective in a hospital setting. In order to accomplish this in two years, the theoretical and practical aspects of the program have been carefully coordinated. In the first semester the student is exposed to the hospital setting and to the tasks performed by an NMT in Introduction to NMT and Hospital Orientation. On the other hand, the clinical practicum where students use the equipment and relate to patients does not begin until the second year, or third semester. By the time the practicum begins, students have considerable knowledge of the basic sciences involved, the language used, and the equipment. They will have

FIGURE 6. NMT CURRICULUM FLOW


SEMESTER 1
SEMESTER 2
SEMESTER 3
SEMESTER 4
SUMMER
Introduction to NMT & Hospital Orientation
Radiation Physics
Radiation Safety & Radiation Biology
Nuclear Instrumentation II
Social Psychology for the Health Sciences
Applied Mathematics
Nuclear Instrumentation I
Clinical Practicum I
Clinical Practicum II
Anatomy, Physiology & Pathology I
Anatomy, Physiology & Pathology II
Clinical Nuclear Medicine Technology I
Clinical Nuclear Medicine Technology II
Communications Skills
Chemistry for the Health Sciences
Radiochemistry & Radiopharmaceuticals
Technical Reporting
Medical Terminology
Clinical Practicum III

the confidence and ability to gain maximum experience and knowledge from their observations of the clinical work.

The following five points have been taken into consideration when designing the curriculum:

1. The curriculum has been designed to meet AMA Essentials of an Accredited Program in Nuclear Medicine Technology.

2. The program graduate will be prepared to pass a national certifying exam for NMTs.

3. The graduates will have a basic foundation in all of the branches of NMT and can later choose to specialize in imaging, in vitro laboratory work, or radiopharmaceuticals if they so desire.

4. Courses in general education are included to help the student to better understand and communicate with people.

5. Class work and laboratory or clinical practicum are integrated to reinforce learning. Lectures generally precede laboratory exercises.

The content of the majority of the courses in the curriculum deals with topics required by the AMA Essentials. On an individual topic level as well as in sum, AMA requirements are everywhere exceeded in this program.

Students receive hospital experience where they are supervised by a clinical instructor - a staff nuclear medicine technologist. The practicum is divided into three phases: observation of procedures, participation under close supervision, and performance under loose supervision. Approximately 1,000 hours are spent in the practicum program.

The relationship between courses is indicated by arrows in the following diagram. Arrows show prerequisites such as Radiation Physics which must precede Radiation Safety, Biology, and Nuclear Instrumentation I. When arrows join courses in the same semester, close coordination between the teachers of these interrelated courses is required.

COURSE OUTLINES AND PERFORMANCE OBJECTIVES

Suggestions for using Performance Objectives

A trend which is becoming increasingly popular in education today is the use of behavioral or performance objectives. We define the term performance objective as a demonstrable knowledge or skill students must master in a given course.

Performance objectives are useful both to the student and the instructor. For the student, performance objectives give an idea of the required depth of knowledge and degree of skills he will need to achieve. For the instructor, performance objectives can supplement the course outline in the design of instructional activities and as a guide in preparing evaluation events. These evaluation events can include both written or oral tests and the demonstration of clinical procedures.

Performance objectives have been designed for all lecture and laboratory courses which cover subjects included in the AMA Essentials of 1969.

It should be noted that there is some overlap of instructional objectives. In a few situations this has occurred because it was not always possible to identify the precise point where one subject interest ended and another began. In other instances objectives on the same topic were given depth treatment in one subject and only introductory or review treatment in another subject section.

Performance objectives are not intended as a comprehensive blueprint for classroom instruction or exams. Although it is recommended that the instructor both teach and test all discrete objectives, performance objectives should not be the exclusive basis for the final exam.

To ensure that students will not simply parrot back performance objectives, we recommend the following teaching technique. Several discrete objectives are synthesized and integrated into a more comprehensive test question to assess depth of knowledge of a subject. The synthesis need not use objectives in consecutive sequence. An example of this teaching technique is illustrated below.

Instructions to the student:

The following nuclear reaction results in the formation of a radioactive daughter nucleus:

$$^{x}_{y}A + n - {}'B + p$$

a. Write the atomic number and mass number of the daughter nucleus.

b. Write the complete equation in its most likely form of radioactive transition.

c. Describe the effects of any particulate radiation emitted in the transition on an absorbing medium.

This physics test problem was based on the following Radiation Physics performance objectives and related knowledge:

MAIN TOPIC: RADIOACTIVITY

5. Describe isobaric transitions. An acceptable response must include completion of the following:

   a. Write the equation for negatron decay positron decay, and electron capture including the production of a neutrino in each case.

   b. Qualitatively relate the probability of negatron decay versus positron decay/electron capture to radionuclides produced by:

      reactors

      cyclotrons

MAIN TOPIC: INTERACTION OF RADIATION WITH MATTER

7. Specify why all charged particles having kinetic energy are capable of producing ionization, excitation, and heat in an absorbing medium. Identify the basic differences in interactions involving heavy particles (protons, alphas) and those involving light particles (positrons, electrons).

Creative problem solving based on case descriptions relating to one or more objectives is another effective use of performance objectives. This technique has been used successfully by a number of institutions and, notably, for the past ten years in the Radiation Safety course offered by Harvard University.

The following is an example of a case description used in a final exam to evaluate the student's problem solving ability:

> An investigator, while opening a vial containing 2 Curies of Phosphorous-32 in solution, cracks the bottle, cutting his hand and splattering the contents into the room (Volume of room = 10^8 cm^3), and over his hands and clothes. The incident takes place in a laboratory occupied at the time by 2 other investigators, a young female technician (over 18), and a 16 year old high school student working as a dishwasher.
>
> Describe the sequence of steps to be taken by the investigator as a result of the accident.

SEMESTER 1

Introduction to NMT and Hospital Orientation

Radiation Physics

Applied Mathematics

Anatomy, Physiology & Pathology I

Communications Skills

INTRODUCTION TO NUCLEAR MEDICINE TECHNOLOGY AND HOSPITAL ORIENTATION

Hours Required
Class, 2; Laboratory, 3

Course Description

INTRODUCTION TO NUCLEAR MEDICINE TECHNOLOGY AND HOSPITAL ORIENTATION is designed to present the student with an overview of the nuclear medicine technology career and curriculum. In addition, the student will observe the role of many of the other hospital departments in providing patient care. These objectives are accomplished through lectures by staff and guest speakers, movies, field trips, and supervised observations at the affiliated hospitals.

Major Divisions

		Semester	
		Class Hours	Lab Hours
I.	Hospital Ethics and Professionalism	2	0
II.	Nuclear Medicine Technology	10	18
III.	Hospital Sepsis and Communicable Diseases	4	6
IV.	Hospital Orientation and Nursing Procedures	12	18
V.	Hospital Employment	2	3
	TOTAL	30	45

I. Hospital Ethics and Professionalism

A. Units of Instruction

1. Definition of terms
2. Need
3. Value
4. Knowledge to be kept in confidence
5. Technician's relationship to patient
6. Technician's relationship to other hospital personnel
7. Legal aspects

II. Nuclear Medicine Technology

A. Units of Instruction

1. Overview
   a. History of nuclear medicine
   b. Description of the field of nuclear medicine
   c. What an NMT does
   d. What an NMT needs to know
2. Radiation safety and radiation biology
3. Radiochemistry and radiopharmacy
4. Clinical nuclear medicine (static and dynamic in vivo studies)
5. Clinical nuclear medicine (in vitro studies)

B. Laboratory Projects

1. Tour by hospital radiation safety officer
2. Observe activities in hospital radiopharmacy or visit radiopharmaceutical supplier
3. Observe static imaging studies
4. Observe dynamic imaging studies
5. Observe in vitro or "wet" studies
6. Visit nuclear medicine research lab or nuclear medicine instrumentation manufacturer

III. Hospital Sepsis and Communicable Diseases

A. Units of Instruction

1. Hospital sepsis
   a. Film - Hospital Sepsis - A Communicable Disease*
   b. Definition of terms
   c. Discussion of film
2. Communicable diseases
   a. Definition of terms
   b. Responsibility for controlling disease
   c. Preventive measures
   d. Disease states
      i. Etiology
      ii. Manifestations
      iii. Transmission
      iv. Prevention barriers
      v. Decontamination

B. Laboratory Projects

1. Visit hospital housekeeping department and discuss cleaning methods
2. Observe culture preparation in hospital microbiology laboratory

IV. Hospital Orientation and Nursing Procedures

A. Units of Instruction

1. IVs and vena punctures
   a. Aseptic techniques
   b. Related Paraphernalia
   c. Techniques
   d. Problems
   e. Demonstration and practice
2. Patient handling - body mechanics
   a. Proper lifting techniques
   b. Moving the patient
   c. Moving a patient in traction or with a cast

   d. Moving a patient with a catheter, IV, or drainage bag in place
   e. Demonstration and practice

3. Emergency complications
   a. Signs and symptoms
   b. Seizures
   c. Drug reactions
   d. Hemorrhage
   e. Insulin shock
4. Vital signs
   a. Pulse
   b. Respiration
   c. Blood pressure
   d. Temperature
   e. Demonstration and practice
5. Cardiopulmonary resuscitation
   a. Film - Prescription for Life**
   b. Definition of cardiac arrest
   c. Types of cardiac arrest
   d. Diagnosing cardiac arrest
   e. Actions to take
      i. Artificial ventilation
      ii. External cardiac massage
   f. Demonstration and practice
6. Hospital emergencies and natural disasters
   a. Fire
   b. Natural disasters
   c. Evacuation procedures
   d. Mass casualties

B.. Laboratory Projects

1. Observe nurses at work, particularly inserting IVs and performing vena punctures
2. Observe radiologic technicians at work, particularly their patient handling techniques
3. Observe surgery in progress
4. Observe inhalation therapists at work
5. Observe the cardiopulmonary unit or the intensive care unit
6. Observe activities in the emergency room

V. Hospital Employment

A. Units of Instruction

1. Registration and professional societies
2. How to get a job as an NMT
   a. Notice of job availability
   b. Effective resume construction
   c. Application form
   d. Interview
      i. Appearance and grooming
      ii. Questions to ask

B. Laboratory Projects

1. Visit with hospital personnel officer or attend local meeting of the Society of Nuclear Medicine, Technologist Section

Texts and References

Maynard, Clinical Nuclear Medicine

Smith and Germain, Nursing of Adults

U.S. Atomic Energy Commission, Division of Technical Information, Nuclear Terms - A Glossary

Additional References

Hospital Procedures Manuals

Visual Aids

American College of Surgeons, 55 Erie Street, Chicago, Illinois 60611

* Hospital Sepsis - A Communicable Disease (ACS#105)
28 min., 16 mm., color, optical sound

** Prescription for Life (ACS#537)
50 min., 16 mm., color, optical sound

PERFORMANCE OBJECTIVES FOR INTRODUCTION TO NUCLEAR MEDICINE TECHNOLOGY AND HOSPITAL ORIENTATION

I. HOSPITAL ETHICS AND PROFESSIONALISM

A. The student should be able to:

1. Discuss the concept of hospital record confidentiality
2. Describe the technician's relationship:
    a. To the patient
    b. To other hospital personnel.

II. NUCLEAR MEDICINE TECHNOLOGY

A. The student should be able to:

1. Summarize the history of nuclear medicine giving:
    a. Its beginnings
    b. Milestones in the development of the field
    c. Present number of hospitals and NMTs employed in U.S.
    d. Rate of growth and future predictions.
2. Describe the field of nuclear medicine.
3. Describe what an NMT does. An acceptable answer shall include both in vivo and in vitro procedures.
4. Explain how each of the following subjects relates to the practice of nuclear medicine technology:
    a. Radiation safety and radiation biology
    b. Radiochemistry and radiopharmacy
    c. Clinical nuclear medicine.

III. HOSPITAL SEPSIS AND COMMUNICABLE DISEASES

A. The student should be able to:

1. Define the term "hospital sepsis."
2. Discuss the following about hospital sepsis:
    a. Etiology
    b. Manifestations
    c. Transmission
    d. Prevention barriers
    e. Decontamination.

IV. HOSPITAL ORIENTATION AND NURSING PROCEDURES

A. The student should be able to:

1. Describe how to insert IVs and to perform vena punctures. An acceptable answer will include:
    a. Aseptic techniques
    b. Related paraphernalia
    c. Problems.

IV. HOSPITAL ORIENTATION AND NURSING PROCEDURES (continued)

2. The student shall demonstrate proper patient handling and discuss special restrictions when:
    a. Patient is in traction or with a cast
    b. Patient has catheter, IV, or drainage bag in place.

3. Discuss emergency complications including signs and symptoms of:
    a. Seizures
    b. Drug reactions
    c. Hemorrhage
    d. Insulin shock.

4. Given the necessary instruments, measure the following vital signs:
    a. Pulse
    b. Respiration
    c. Blood pressure
    d. Temperature.

5. Describe the types of cardiac arrest and demonstrate actions to take. Actions should include:
    a. Artificial ventilation
    b. External cardiac massage.

6. Discuss hospital emergency evacuation procedures.

V. HOSPITAL EMPLOYMENT

A. The student should be able to:

1. Describe how to get a job as an NMT. A correct response shall include:
    a. Passing registration exam
    b. Locating job
    c. Writing resume
    d. Good interview technique.

RADIATION PHYSICS

Hours Required

Class, 3; Laboratory, 0

Course Description

RADIATION PHYSICS has been designed to provide the minimum background for the effective functioning of the nuclear medicine technician. The student is introduced to the concept of energy and its various forms which is then applied to the fundamental structure of the atom and nucleus. The different types of radiation are defined and described in depth. The section on radioactivity builds on this framework to describe the circumstances under which the radiations are emitted and also to provide complete familiarity with the practical mathematics of radioactive decay and the common radiation units. This topic occupies almost one third of the course time, and coverage in depth is essential. Equal depth comprehension is required for understanding the interaction of radiation with matter. The interaction of radiation with solids, liquids, and gases is given broad, overall treatment, thus providing an essential basis for the understanding of radiation detectors.

APPLIED MATHEMATICS should be given concurrently with this one-semester course. Laboratory work is not included.

Major Divisions

		Semester Class Hours
I.	Mass and Energy	4
II.	Atomic Structure	4
III.	Radiation Chemistry and Radiochemistry (definitions)	1
IV.	Ionizing Radiations	7
V.	Radioactivity	14
VI.	Radiation Units	3
VII.	Interaction of Radiation and Matter	12
	Total	45

I. Mass and Energy

1. Definitions
2. Forms (kinetic and potential, etc).
3. Energy units
4. Relationships

II. Atomic Structure

1. Nomenclature
2. Model of the atom
3. Model of the nucleus
4. Atomic and mass numbers
5. Isotopes, isobars, isotones, isomers, and radionuclides (definitions)
6. Mass defect and binding energy

III. Radiation Chemistry and Radiochemistry (definitions)

IV. Ionizing Radiations (definitions and description of the ionization process)

1. Electromagnetic
   a. Definitions and examples
   b. Wavelength, frequency, and energy
   c. Electromagnetic spectrum
   d. Production of X-rays--continuous spectra
   e. Production of X-rays--characteristic spectra
   f. Gamma radiation (natural and artificial sources)
2. Particulate radiation
   a. Definition
   b. Examples

V. Radioactivity

1. Factors influencing nuclear stability
2. Nuclear disintegration processes
   a. Alpha decay
   b. Isobaric transitions
      1) Beta decay
      2) Positron decay
      3) Electron capture
   c. Isomeric transitions
      1) Gamma ray decay
      2) Internal conversion
   d. Math of decay (units of activity, half-life, mean life formulas and decay curves, parent-daughter relationships)
3. Production methods
   a. Nuclear reactors
   b. Particle accelerators
   c. Fission
   d. Radionuclide generators
4. Specific Activity
5. Physical characteristics of commonly used radionuclides (chemical or physical form, type and energy of emission, half-life, etc.)
6. Internal dosimetry
   a. Basic factors (nuclear and biological parameters)
   b. Dosimetric assumptions
   c. Medical Internal Radiation Dose Committee Schema
   d. Formulas

VI. Radiation Units

1. Roentgen and Subdivisions
2. Rad, RBE, Rem, etc.

VII. Interaction of Radiation and Matter

1. Atomic interactions
    - a. Photoelectric effect
    - b. Compton scattering
    - c. Pair production
    - d. Bremsstrahlung
    - e. Others
2. Specific ionization
3. Radiation absorption
    - a. Absorption coefficients
    - b. Absorption curves and formulas
    - c. Half-value layer

Texts and References

Early, Razzak, and Sodee. Textbook of Nuclear Medicine Technology.

Quimby and Feitelberg. Radioactive Nuclides in Medicine and Biology - Basic Physics and Instrumentation

Simmons. A Training Manual for Nuclear Medicine Technologists

Wagner. Principles of Nuclear Medicine

PERFORMANCE OBJECTIVES FOR RADIATION PHYSICS

I. MASS AND ENERGY

A. The student should be able to:

1. State the units of mass, length, and time in a consistent unit system.
2. Define work in terms of force and distance, and carry out simple numerical calculations involving these quantities, including the appropriate units.
3. Define energy in terms of the ability to do work.
4. Identify different forms of energy, to include as a minimum:
   a. Kinetic
   b. Potential
   c. Chemical
   d. Electrical
   e. Solar.
5. State the law of conservation of energy.
6. State the relationship of equivalence between mass and energy.
7. Define the electron volt and then relate it to other units of energy.
8. Identify the physical quantities in the formula for the calculation of electrostatic force,

$$F \propto \frac{q_1 \cdot q_2}{d^2} .$$

II. ATOMIC STRUCTURE

A. The student should be able to:

1. Identify all components of the Bohr model of the atom using the proper nomenclature for the subatomic particles and the electron orbits.
2. Construct a table showing the magnitude and sign of the charge of the electron, proton, and neutron, and their relative masses.
3. Draw a diagram illustrating the relative binding energies of electrons in different orbital levels.
4. Describe qualitatively the effect of atomic number on orbital radius and on the magnitude of the binding energies.

II. ATOMIC STRUCTURE (continued)

5. Using the diagram of objective #3, define and differentiate the terms excitation and ionization.

6. Using the diagram of objective #3, describe the processes of de-excitation and the consequent emissions of energy. To be acceptable the student must state the fact that these energies are equal to the difference in binding energy between the electron orbits involved and are thus characteristic of that particular species of atom.

7. Define the following terms:
   a. Atomic number
   b. Mass number
   c. Isotope
   d. Isomer
   e. Isobar
   f. Nuclide.

   In addition, students must be able to identify isotopes, isomers, and isobars from given groups of nuclides.

8. Describe a simple model of the nucleus, including as a minimum:
   a. The presence of protons and neutrons
   b. The presence of a strong nuclear force able to overcome the electrostatic repulsion between positively charged protons.
   c. The presence of discrete, unique energy levels within the nucleus which can be inhabited by no more than a fixed number of nucleons.
   d. The possibility of excitation and de-excitation of nucleons between the nuclear energy levels.

III. RADIATION CHEMISTRY AND RADIOCHEMISTRY DEFINITIONS

(See RADIOCHEMISTRY and RADIOPHARMACY performance objectives.)

IV. IONIZING RADIATIONS

A. The student should be able to:

1. Identify as a minimum the following characteristics of electromagnetic radiation:
   a. The presence of both electric and magnetic fields.
   b. The association of energy transmission with electromagnetic radiation.
   c. That photons possess both wave nature and particulate properties, but that in NM events may be described in terms of photons being "particles."

2. Define the terms "wavelength" and "frequency" with appropriate units.

IV. IONIZING RADIATIONS (continued)

3. Write the equation relating the velocity of a wave to its wavelength and frequency.
4. Write the equations relating the energy of an electromagnetic photon to both its frequency and wavelength, identifying qualitatively Planck's constant and the velocity of light in vacuo.
5. Describe, qualitatively, the electromagnetic spectrum in terms of photon energy, wavelength, and frequency identifying as a minimum radio waves, visible light, and X and γ radiation.
6. Define the term "Bremsstrahlung." To be acceptable the definition must include the following:
    a. Production of Bremsstrahlung is the result of the interaction between a charged particle and a nuclear field.
    b. The electromagnetic radiation produced exhibits a continuous energy spectrum.
    c. The maximum energy of the radiation spectrum cannot exceed that of the incident charged particle.
7. Describe the production of characteristic X-rays, including as a minimum:
    a. The energy requirements for ionization or excitation of an orbital electron.
    b. That any orbital vacancy so created will be refilled by an electron.
    c. That any electron filling this vacancy, whether from outside the atom or from a higher energy level, must emit energy in the form of an electromagnetic photon or in the kinetic energy of an ejected (Auger) electron.
    d. That the total energy release is equal to the difference between the binding energies of the electron orbits involved in the transition.
    e. That electron movement between orbits which are not adjacent may be accomplished in one or more transitions between orbits, each transition being associated with the emission of a photon of specific energy.
    f. That characteristic X radiation produces a line energy spectrum as opposed to a continuous energy spectrum.
    g. That such a line spectrum is unique to the nuclide involved.

V. RADIOACTIVITY

A. The student should be able to:

V. RADIOACTIVITY (continued)

1. Define radioactivity in terms of unstable nuclei which can spontaneously de-excite by emission of radiation.
2. Identify the influences on nuclear stability exerted by neutron:proton ratio.
3. Differentiate between natural and artificial radioactivity.
4. Identify charge and mass number as quantities which must be conserved in any nuclear transition. To be acceptable, students must be able to derive A and Z of a daughter nuclide given the A and Z of the parent and the symbols only for any other particles involved in a nuclear reaction, e.g. n, p, α, γ.
5. Describe isobaric transitions. As a minimum students must:
    a. Write the equations for negatron decay, positron decay, and electron capture including the production of a neutrino in each case.
    b. Identify the necessity for a minimum total de-excitation energy for positron decay and state its value.
    c. Describe the reason for the emission of a characteristic X-ray and Auger electrons after electron capture.
    d. Identify positron decay and electron capture as competitive processes, where positron decay is energetically possible.
    e. Qualitatively relate the probability of negatron decay versus positron decay/electron capture to radionuclides produced by:
        i. Reactors
        ii. Cyclotrons.
6. Describe isomeric transitions. To be acceptable, the description must include the following:
    a. That the transition involves a rearrangement of nucleons without change of A and Z.
    b. That a nucleon moving from a higher to a lower energy level will lose energy precisely equal to the difference between the 2 energy levels, usually as a γ photon.
    c. That isomeric transitions may follow or lead to isobaric transitions.
    d. The process of internal conversion, including the emission of a conversion electron and X-ray, and identification of the competitive nature of the photon emission and conversion processes.
7. Describe qualitatively the process of "alpha decay" and explain why alpha emitters are not useful in NM procedures.
8. Define the term "metastable."

9. Identify and state the physical meaning of each term in the radioactivity decay equation:

$$N = N_0 e^{-\lambda t} .$$

10. Define the term "half-life" and write the equation relating it to the decay constant.
11. Define the term "mean life" and write the formula relating it to the decay constant.
12. Define the Curie as the unit of radioactivity and state the disintegration rates denoted by "millicurie" and "microcurie."
13. Draw a radioactive decay curve on semilogarithmic graph paper given only the half-life of the radionuclide and use this graph to determine the fraction remaining after a given elapsed time.
14. Calculate the percentage of a particular radionuclide present given the activity at a specified time using the radioactive decay formula and a slide rule or table of natural logarithms.
15. Describe sequential decay and radioactive equilibrium including as a minimum:
    a. That radioactive equilibrium can exist only where a daughter nuclide is radioactive and has a shorter half-life than the parent radionuclide.
    b. That a sequential decay system decays with the apparent half-life of the parent.
    c. That at equilibrium the activities of parent and daughter are often approximately equal.
    d. That sequential decay forms the basis for radionuclide generators.
16. Define physical half-life, biological half-life, and effective half-life; write the formula relating them.
17. Define the term "absorbed dose."
18. State the factors which are important in determining the absorbed dose from an internally administered radionuclide, and the reasons for their importance, including as a minimum:
    a. The types and energies of the radiations emitted and the frequency of emission.
    b. Both the physical and biological half-lives.
    c. The concentration of the radionuclide.
    d. The size and shape of the organ in the case of penetrating radiation.
    e. The absorbed fraction for X and γ rays.

V. RADIOACTIVITY (continued)

19. State the units for the specific gamma ray constant, and identify the fact that this term refers to all penetrating radiation emitted by a particular radionuclide.

VI. RADIATION UNITS

A. The student should be able to:

1. Define the term "roentgen" and describe exposure as the amount of charge liberated in air by X or γ radiation emitted by a particular radionuclide.
2. Define the terms "Rad," "RBE," "quality factor," and "Rem."

VII. INTERACTION OF RADIATION AND MATTER

A. The student should be able to:

1. Describe the photoelectric interaction process, including:
   a. That it involves an interaction between an electromagnetic photon and an entire atom, but in the region of the nucleus.
   b. That in this process the electron transfers all of its energy, less the binding energy, to a bound electron.
   c. That the electron is ejected as a photoelectron whose kinetic energy is equal to the incident photon energy less the original binding energy of the electron.
   d. That this process causes vacancies in electron energy levels, but that when filled, lead to the emission of characteristic X-rays and low-energy electrons.
2. State qualitatively how the probability of a photoelectric interaction varies with the energy of the incident photon and the atomic number of the absorbing medium.
3. Describe the Compton collision process, including:
   a. That this involves an interaction between an electromagnetic photon and a free or loosely bound electron.
   b. That in the process, the photon transfers part of its energy to the electron and is deflected from its original path.
   c. That the angle of deflection is directly related to the amount of energy lost by the photon.
   d. That the maximum energy loss of the photon occurs when the photon scattering angle is 180^{o}.
   e. That the electron acquiring energy in this process is termed a Compton electron.
   f. That the Compton-scattered photon may go on to be involved in subsequent absorption processes.

VII. INTERACTION OF RADIATION AND MATTER (continued)

4. Describe pair production, including:
    a. That this involves the interaction between an electromagnetic photon and a nuclear field.
    b. That this process cannot take place if the photon has an energy of less than 1.022 Mev.
    c. That the photon ceases to exist and gives rise to a positron and negatron as kinetic energy.
5. Identify on a graph of absorption probability versus photon energy the approximate energy ranges where the probability of the photoelectric, Compton, and pair production processes are greatest for tissue and for lead.
6. State the reason for the occurrence of absorption edges in the low energy region of the absorption probability graph, and describe qualitatively the relationship between the energy at which these edges occur and the atomic number of the absorbing medium.
7. Specify why all charged particles having kinetic energy are capable of producing ionization, excitation, and heat in an absorbing medium. Identify the basic differences in interactions involving heavy particles (protons, alphas) and those involving light particles (positrons, electrons).
8. Describe the characteristics of specific ionization and arrange alpha particles, electrons, and γ rays in order of decreasing specific ionization. To be acceptable, the description must reference the fact that this order holds for increasing range in an absorbing medium.
9. Describe the production of annihilation radiation including as a minimum:
    a. That positrons quickly lose kinetic energy by collisions with the surrounding medium.
    b. That a positron with no significant kinetic energy is most likely to combine with an electron to produce two gamma ray photons.
    c. That the energy of each photon is 511 Kev and their combined energy is equal to the rest mass of the positron and electorn.
    d. That the γ ray photons are emitted at an angle of approximately 180^{0}.
10. Identify each term and its physical meaning in the formula for the attenuation of electromagnetic radiation:

$$I = I_0 e^{-\mu X}.$$

VII. INTERACTION OF RADIATION AND MATTER (continued)

11. State the relationship between linear attenuation coefficient, and the mass attenuation coefficient, and rewrite the above formula interchanging one coefficient for the other.
12. Describe the particular characteristics of photon energy and the attenuating medium which influence the magnitude of the attenuation coefficients. To be acceptable, the description must indicate that this is a function of all components of the attenuation coefficients.
13. Define the term "half-value layer" and state the relationship between H.V.L. and the linear attenuation coefficient.
14. Plot a graph of I/I_0 versus distance on semilogarithmic graph paper given only the half-value layer.
15. Calculate the value of one of the quantities in the attenuation formula when numerical values are given for the other 3 quantities using a slide rule, table of natural logarithms, or the graphical method.

APPLIED MATHEMATICS

Hours required
Class, 3; Laboratory, 0

Course Description
APPLIED MATHEMATICS enables the student to perform all basic mathematical computations relevant to the routine practice of nuclear medicine technology. These computations require the use of arithmetic rounding off numbers, scientific notation, slide rule, algebra, basic trigonomietry, logarithms, and graphing.

The order of presenting these topics can be altered if the instructor desires.

Major Divisions

		Semester Class Hours
I.	Review	6
II.	Rules for Rounding Off Numbers	2
III.	Scientific Notation	3
IV.	Slide Rule	3
V.	Rules of Algebraic Manipulations	9
VI.	Basic Trigonometric Functions	6
VII.	Logarithms (Common and Natural)	10
VIII.	Graphing	6
	Total	45

I. Review of Arithmetic
- A. Arithmetic of Whole Numbers
- B. Arithmetic of Common Fractions and Mixed Numbers
- C. Arithmetic of Decimal Fractions and Percents
- D. Arithmetic of Measures
- E. Ratio Problems

II. Rules for Rounding Off Numbers
- A. Definitions of "Significant Figure"
- B. Rounding off in Addition and Subtraction
- C. Rounding Off in Multiplication or Division

III. Scientific Notation
- A. Conversion of Whole Numbers or Decimals into Scientific Notation
- B. Arithmetic Operations on Numbers Expressed in Scientific Notation

IV. Slide Rule
- A. Operations of Multiplication and Division
- B. Ratio and Proportion Problems
- C. Operations on Squares and Square Roots
- D. Operations on Cubes and Cube Roots

V. Rules of Algebraic Manipulations
- A. Algebraic Terminology
- B. Addition, Subtraction, Multiplication, and Division of Monomials
- C. Operations with Exponents
- D. Solution of Equations with One Unknown
- E. Applications of Equation Solution in NMT, e.g. Dose Calculation

VI. Basic Trigonometric Functions
- A. Definitions of the Six Trigonometric Functions
- B. Use of Tables in Trigonometric Functions
- C. Application of Trigonometric Functions in NMT, e.g. Compton Scattering

VII. Logarithms (Common and Natural)
- A. Use in Multiplication and Division
- B. Use in Raising a Number to a Power
- C. Use in Finding a Root
- D. Application of Logarithms in NMT, e.g. Radioactive Decay

VIII. Graphing
- A. Graphing Linear Equations
- B. Graphing Exponential Functions
- C. Application of Exponential Graphing to NMT, e.g. Radioactive Decay

Texts and References

Ayres. Trigonometry

Gossage. Basic Mathematical Skills

Hauck. Trigonometry Review Manual

Heywood. A First Program in Mathematics

Person. Essentials of Mathematics

Reigh and Hauck. Algebra Review Manual

Rice and Knight. Technical Mathetmatics with Calculus

Riggenbach. The Slide Rule with Electronic Applications

Sommers. The Slide Rule and How to Use It

Washington. Introduction to Technical Mathematics

PERFORMANCE OBJECTIVES FOR APPLIED MATHEMATICS

I. REVIEW OF ARITHMETIC

A. The student should be able to:

1. Solve problems involving addition of whole numbers, decimals, or a combination of these.
2. Solve problems involving subtraction of whole numbers, decimals, or a combination of these.
3. Solve problems involving the addition of common fractions or mixed numbers, or a combination of these.
4. Solve problems involving the subtraction of common fractions or mixed numbers, or combinations of these.
5. Solve problems involving multiplication of whole numbers, decimals, or a combination of these and reduce answers to lowest terms.
6. Solve problems involving multiplication of fractions or mixed numbers and reduce the answers to lowest terms.
7. Divide whole numbers, decimals, or a combination of these and reduce the answer to lowest terms.
8. Divide common fractions and mixed numbers or a combination of these and reduce the answer to lowest terms.
9. Change a common fraction to a decimal and a decimal to a common fraction and reduce the answer to lowest terms.
10. Change percent to decimals and decimals to percent.
11. Compute the area of a circle, triangle, and rectangle writing from memory the appropriate formulas required.
12. Convert physical measurements such as mass, volume, and length from the metric system to the U.S. system and from the U.S. system to the metric system.
13. Define the prefixes of multiples and submultiples of units such as milli, kilo, centi, pico, etc.
14. Express values of one multiple or submultiple in terms of another, such as 10^3 microcuries = 1 millicurie.
15. Establish a proportion between two ratios and solve for the unknown quantity such as:

$$\frac{5 \text{ mCi}}{5{,}693 \text{ c/m}} = \frac{X \text{ mCi}}{3{,}152 \text{ c/m}}$$

II. RULES FOR ROUNDING OFF NUMBERS

A. The student should be able to:

1. Define the term "significant figure."
2. Round off numbers to the desired number of significant digits by dropping one or more digits to the right.
3. Memorize the rules for handling zeros in determining the number of significant figures.
4. Round off an addition or subtraction answer.
5. Round off a multiplication or division answer to contain only as many significant figures as are contained in the least exact factor.

III. SCIENTIFIC NOTATION

A. The student should be able to:

1. Change whole numbers or decimals into scientific notation.
2. Change numbers expressed in scientific notation to the corresponding decimal number.
3. Divide numbers expressed in scientific notation such as:

$$\frac{6.3 \times 10^4}{4.8 \times 10^8} =$$

4. Multipy any numbers expressed in scientific notation such as:

$$(4.3 \times 10^6)\ (8.4 \times 10^{-7}) =$$

5. Add a series of numbers expressed in scientific notation having different powers by converting all to a common power.
6. Subtract two numbers expressed in scientific notation having different powers by converting all to a common power.
7. Find the power of a number raised to some power in scientific notation.
8. Transfer a number expressed in scientific notation, from the numerator to the denominator of a fraction, or vice versa, by changing the sign of the exponent.

IV. SLIDE RULE

A. The student should be able to:

1. Read numbers on all scales of the slide rule, interpolating when necessary.

IV. SLIDE RULE (continued)

2. Identify all parts of the slide rule and explain their function by name and location.
3. Multiply numbers on the slide rule using the C and D scales, the CF and DF scales, or a combination of all four.
4. Divide numbers on the slide rule using the C and D scales, the CF and DF scales, or a combination of all four.
5. Calculate percentages on the slide rule using the C and D scales, the CF and DF scales, or a combination of all four.
6. Find the reciprocal of a number on the slide rule using the C-CI, D-DI, or CF-CIF scales.
7. Solve ratio and proportion problems of the form $\frac{4\text{ mCi}}{7\text{ units}} = \frac{X\text{ mCi}}{13\text{ units}}$ using the C and D scales, the CF and DF scales, or a combination of these four scales on the slide rule.
8. Find the square root of a number on the slide rule by using the D scale and the appropriate portion of the A scale.
9. Square a number on the slide rule by using the A and D scales.
10. Find the cube root of a number on the slide rule by using the D scale and the appropriate portion of the K scale.
11. Cube a number on the slide rule by using the K and D scales.

V. RULES OF ALGEBRAIC MANIPULATIONS

A. The student should be able to:

1. Define algebraic terminology such as coefficient, monomial, binomial, terms, base, exponent, factor, constant, unknown, subscript, superscript, prime mark, equation, and algebraic expression.
2. Add, subtract, multiply, and divide signed numbers.
3. Add and subtract monomials with like and unlike terms.
4. Identify and define exponent (power) and base.
5. Multiply and divide monomials.
6. Multiply algebraic quantities expressed as power of the same base.
7. Multiply bases having like exponents.

V. RULES OF ALGEBRAIC MANIPULATIONS (continued)

8. Divide algebraic quantities expressed as powers of the same base.
9. Divide bases having like exponents.
10. Find the corresponding value of any quantity raised to a positive or negative power, or the zero power.
11. Factor a polynomial by removing the common terms.
12. State the four axioms used to solve equations.
13. Solve an equation with one unknown.
14. Convert a written statement into an algebraic expression such as, a photon flux varies inversely as the square of the distance, $F \propto \frac{1}{d^2}$.
15. Convert a word problem into an algebraic equation and solve for the unknown quantity.
16. Solve for a given unknown in a formula such as $E_\beta = 1/2\ mv^2$.
17. Solve direct variations such as $E = h\nu$, inverse variations such as $\lambda N = \frac{dN}{dt}$, and joint variations such as $K = \frac{\{R_c\}\{x^+\}}{\{R_x\}\{c^+\}}$.

VI. BASIC TRIGNOMETRIC FUNCTIONS

A. The student should be able to:

1. Draw or measure an angle.
2. Write from memory the definitions of the six trigonometric functions.
3. Using tables, find the natural functions of any given angle or, given the angle, find the natural function.
4. Use the trigonometric ratios of sine, cosine, and tangent to solve right triangle problems.
5. Solve a problem such as : $E_{\gamma'} = \dfrac{E_\gamma}{1 + \frac{E_\gamma}{511}(1 - \text{Cos}\,\phi)}$ where E_γ and ϕ are given, solve for $E_{\gamma'}$, or where E_γ and $E_{\gamma'}$ are given, solve for ϕ, by using a table of trigonometric functions.

VII. LOGARITHMS

A. The student should be able to:

1. Define the basic properties of logarithms in terms of the basic properties of exponents.
2. Solve multiplication and division problems using logarithms.
3. Raise a number to a power by using logarithms.
4. Find the root of a number by using logarithms.
5. Define the logarithm of a number as being the exponent or power of a given base that is required to produce that number.
6. Identify the terms: common logarithms, Briggsian logarithms, and logarithms to the base 10 as being one and the same.
7. Identify and define characteristic and mantissa.
8. Find the mantissa of the log of a number by using a table and interpolating when necessary.
9. Determine by inspection the characteristic of a number.
10. Define the antilogarithm of a number as the number corresponding to a given logarithm.
11. Find the antilog, or the number, corresponding to a given logarithm from a table, interpolating when necessary.
12. Find the mantissa of the logarithm of a number using the D and L scales of the slide rule.
13. Find the antilog of the logarithm of a number using the D and L scales of the slide rule.
14. Given any number greater than 1.0, look up the corresponding natural logarithm on the slide rule using the appropriate LL and D scales, placing the decimal point according to the LL scale used.
15. Given any number less than 1.0, look up the corresponding natural logarithm on the slide rule, using the appropriate LL0 and D scale.
16. Find the value of a number raised to some power by using the appropriate log scale and the C and D scales on the slide rule.
17. Find the value of "e" raised to some positive or negative power, such as e^6 or e^{-6}, using the appropriate log scale and the D scale on the slide rule.
18. Solve a decay problem of the form $A = A_0e^{-\lambda t}$ by using the C, D, and LL scales on the slide rule.

VII. LOGARITHMS (continued)

19. Solve a decay problem of the form $A = A_0e^{-\lambda t}$ by using a table of exponential functions values where x and e^{-x} values are given.

VIII. GRAPHING

A. The student should be able to:

1. Define the terms "abscissa" and "ordinate."
2. Label the quadrants and plot points on a rectangular coordinate system.
3. Graph equations of the first degree, i.e., linear equations.
4. Identify linear axes as having both the ordinate and abscissa divided into equal line segments.
5. Identify semilogarithmic axes as having the ordinate line segments spaced according to logarithms of numbers while abscissa line segments are spaced equally.
6. Identify logarithmic axes as having both the ordinate and abscissa divided according to logarithms of numbers.
7. Plot the value of one variable associated with distance along the ordinate axis and plot the value of the other variable associated with distance along the abscissa axis.
8. Locate a point on the graph representing the pair of values plotted directly above the first variable's value on the abscissa and directly across from the other variable's value on the ordinate.
9. Graph a function relating to pairs of variables by drawing a line through all points for which pairs of numbers have been acquired.
10. Plot an exponential function, on linear graph paper, such as: $A = A_0e^{-\lambda t}$, and plot an exponential function on semilogarithmic graph paper such as $A = A_0e^{-\lambda t}$.
11. Construct a radioactive decay curve by plotting values derived from the formula $A/A_0 - (1/2)^n$ on semilogrithmic paper.

ANATOMY, PHYSIOLOGY, AND PATHOLOGY I

Hours Required

Class, 3; Laboratory, 2

Course Description

ANATOMY, PHYSIOLOGY, AND PATHOLOGY I provides the student with an understanding and insight into the anatomic and physiologic basis for the studies performed in nuclear medicine. The course also acquaints the student with some of the nuclear medicine procedures relevant to the organ systems studied, while introducing the correlation between primary course material and the clinical procedures to be performed later in training. Examples of disease processes relevant to the subject matter are introduced.

Major Divisions		Semester Class Hours	Semester Lab Hours
I.	Cellular and Tissue Biology	4	4
II.	Skin	1	0
III.	Skeletal and Articular System	4	6
IV.	Nervous System	10	8
V.	Reproductive System	11	6
VI.	Endocrine System	11	0
VII.	Muscular System	2	4
VIII.	Fluids and Electrolytes	2	2
	Total	45	30

I. Cellular and Tissue Biology

A. Units of Instruction

1. Cell
    - a. Structures composing animal cells
    - b. Functions of cellular structures
    - c. Cellular physiologic processes
        - i. Introduction to transport system, cellular metabolism, and cell multiplication
2. Tissues
    - a. Classification of tissues
        - i. Embryologic, i.e., three primordial layers
        - ii. Four major divisions of tissues and their primary subdivisions
    - b. Structure and function of specialized tissue, e.g. cardiac muscle, striated muscle

B. Laboratory Projects

1. Introduction to the microscope
2. Microscopic examination of cells and identification of cellular components
    - a. Label appropriate illustrations
3. Mitosis
    - a. Identify the phases of mitosis
    - b. Label appropriate illustrations
4. Microscopic evaluation of a variety of tissues, e.g. skin, intestine, cardiac muscle, bone

II. Skin

A. Units of Instruction

1. General
    - a. Structure
        - i. Layers of the skin
        - ii. Skin accessory organs, e.g. hair follicles, sweat glands
    - b. Function of the skin and its accessory organs
    - c. Introduction to granulation response

III. Skeletal and Articular System

- A. Units of Instruction
  - 1. Skeletal system
    - a. Function of the skeletal system
    - b. Introduction to bone embryology
    - c. Introduction to bone histology
    - d. Classification of bones
    - e. Bones comprising the two major skeletal divisions
      - i. Axial skeleton, e.g. vertebral column, ribs
      - ii. Appendicular skeleton, e.g. humerus, radius, ulna, carpal bones, metacarpals, phalanges
    - f. Introduction to physiology
      - i. Bone growth and hemeostasis
      - ii. Bone repair
  - 2. The articular system
    - a. Function of the articular system
    - b. Classification of joints
    - c. Structure of joints and their function
  - 3. Introduction to pathologic conditions affecting the skeletal and articular systems, e.g. primary and metastatic bone neoplasms, osteoporosis, osteomyeletes, rheumatoid arthritis, osteoarthritis
  - 4. Introduction to nuclear medicine procedures relating to the skeletal and articular systems, e.g. radionuclide bone imaging. radionuclide joint imaging, radionuclide bone densitometry
- B. Laboratory Projects
  - 1. Gross anatomy of bones
    - a. Identify the bones of an articulated skeleton
      - i. Label an appropriate illustration
    - b. With bone from a disarticulated skeleton, identify the more important anatomic segments and prominences. Include the skull, vertebra, innominate bones (pelvic bone) and the long bones. Label diagrams.
    - c. Examine radionuclide total body bone scans and compare with the labeled illustrations of the skeleton.
  - 2. Histology of bones
    - a. Examine under the microscope prepared histologic sections of bone and identify the major components.
  - 3. Anatomy and physiology of joints
    - a. Examine prepared specimens of the three types of articulations.
    - b. Demonstrate various types of joint movements.

IV. Nervous System

- A. Units of Instruction
  - 1. General
    - a. Brief survey of embryological development
    - b. Structure and functions of the neuroglia
    - c. Neurons
      - i. Classification of neurons
      - ii. Structure and functions of the neuron and its component parts
      - iii. Physiology of neuron activity, reflex arc
    - d. Major divisions and subdivisions of the nervous systme
      - i. Central nervous system
        - (a) Brain
        - (b) Spinal cord
      - ii. Peripheral nervous system
        - (a) Cranial nerves
        - (b) Spinal nerves
        - (c) Autonomic nervous system
  - 2. Brain
    - a. General anatomy of the brain
      - i. Gray and white matter
      - ii. Hemispheres, sulci, fissures, etc.
    - b. Location, structure, and function of major divisions of the brain
      - i. Telencephalon (cerebrum)
        - (a) Four primary lobes, etc.
      - ii. Diencephalon
        - (a) Thalamus
        - (b) Hypothalamus
      - iii. Mesencephalon (midbrain)
        - (a) Four nuclear masses
      - iv. Metencephalon
        - (a) Pons
        - (b) Cerebellum
      - v. Myelencephalon
        - (a) Medulla oblongata
      - vi. Ventricles and basal cisterns
        - (a) Location, structure, and function
      - vii. Meninges
        - (a) Location, structure, and function
      - viii. Cranial nerves
        - (a) Introduction to the function of the 12 cranial nerves

3. Spinal cord and spinal nerves
    a. Location, structure, and function of spinal cord and nerves
        i. Afferent and efferent nerve tracts
        ii. Reflex arc and nerve plexis
4. Cerebrospinal fluid
    a. Origin, site of reabsorption, composition, and functions
5. Cerebral vasculature
    a. Anatomic relationship of the major arterial and venous intracerebral vessels and including the carotids, internal and external carotids, and the jugular veins.
6. Special senses
    a. Location, structure, and functions of the visual auditory, olfactory, and gustatory senses
    b. Survey of the physiology of vision, hearing, smell, and taste
7. "Blood Brain Barrier"
    a. Theory of the blood brain barrier with emphasis on its relationship to brain imaging
8. Introduction to pathologic conditions affecting the nervous system
    a. Include major cerebral and spinal cord neoplasms, cerebrovascular accidents, cerebral contusions, hematomas, abscesses, subdural and epidural hematomas, communicating and noncommunicating hydrocephalus, cerebrospinal fluid rhinorrhea
9. Introductory survey of nuclear medicine nervous system procedures, e.g. radionuclide cisternograms, radionuclide cerebral angiograms and static cerebral imaging studies, cerebral blood flow studies

B. Laboratory Projects
1. Gross anatomy
    a. Class demonstration of the location and appearance of the major divisions of the human brain from prepared specimens and models of the brain
        i. Label appropriate diagrams.
    b. Class demonstration and/or participation in the dissection of an animal brain (sheep)
    c. Demonstration of a prepared specimen or model demonstrating the anatomic location of the cranial nerves as they arise from the brain
    d. Demonstration of a prepared specimen and/or model of the spinal cord and spinal nerves
        i. Label a diagram of the cross section of the spinal cord.
    e. Demonstration of a prepared specimen or model of the autonomic system
    f. Radiographic contrast cerebral arteriogram and pneumoencephalogram
2. Histology
    a. Examine prepared slides of nervous tissue and identify the component structures.
3. Physiology
    a. Laboratory preparation demonstrating the reflex arc in the frog
    b. Demonstration of an anesthetized normal and a decerebrate frog and their responses to various stimuli (elective)
    c. Demonstration of reflex arc in the human
        i. Patellar reflex, achilles reflex, pharyngeal reflex, etc.
    d. Demonstration of blood perfusion in the brain by images obtained during a radionuclide cerebral angiogram
4. Special senses
    a. Eye
        i. Anatomy
            (a) Demonstration of the structures composing the eye using prepared specimens or models
            (b) Dissection of an animal eye and labeling an appropriate diagram
        ii. Physiology
            (a) Demonstration of pupillary response, the blind spot, and functions of the lens
    b. Ear
        i. Anatomy
            (a) Demonstration of the structures composing the ear using models or prepared specimens
        ii. Physiology
            (a) Demonstration of the vestibular and auditory functions of the ears
    c. Taste, smell, pain, and touch, heat and cold perception (elective)
        i. Demonstrate the four taste sensations.
        ii. Demonstration of olfactory perceptions
        iii. Demonstrate the distribution of pain, touch, and temperature perceptions.

V. Reproductive System

A. Units of Instruction

1. Male reproductive system
    - a. Location and structures comprising the male reproductive organs
        - i. Gross anatomy, e.g. penis, prostate, seminal vesicles
        - ii. Microscopic anatomy, e.g. Sertoli cells, interstitial cells of Leydig, germinal epithelium
    - b. Function of the organs and their constituent parts, e.g. functions of the testes, hormones produced, their origin and functions
    - c. Brief survey of the embryologic development of the reproductive system
2. Female reproductive system
    - a. Location and structures comprising the female reproductive organs
        - i. Gross anatomy, e.g. vulva, vagina, uterus, uterine cervix, ovaries, uterine tubes
        - ii. Microscopic anatomy, e.g. graafian follicles, layers of the uterine wall
    - b. Function of the organs and constituent parts
        - i. Functions of the ovary, uterus, uterine tubes, etc.
        - ii. The hormones produced, their origin and functions
        - iii. Hormonal interrelationship between the adenohypophysis and the ovary
    - c. Menstrual cycle and menopause
        - i. Introduction to the physiology of the menstrual cycle and menopause
3. Mammary glands
    - a. Structure and function of mammary glands
4. Gametogenesis
    - a. Cell Division
        - i. Mitosis
        - ii. Meiosis
    - b. Spermatogenesis
    - c. Oogenesis
5. Introduction to genetics
    - a. Concept of chromosomes, genes, DNA.
    - b. Simple Mendelian laws
    - c. Sex determination
6. Survey of steps in embryologic development from fertilization through cleavage, implantation, placental formation, trimester fetal development, and delivery.

VII. Introduction to pathologic and normal conditions affecting the reproductive system, e.g. Normal - pregnancy; Pathologic - placenta previa, sterility, neoplasms

VIII. Introduction to nuclear medicine procedures related to the reproductive system, e.g. radionuclide placentography, radionuclide placental imaging, radioimmunoassay studies

B. Laboratory Projects

1. Gross anatomy
    - a. Demonstration of male and female reproductive organs as to their location and appearance by use of models and prepared specimens
2. Histology
    - a. Examination of prepared tissue slides of the testes
    - b. Examination of the prepared tissue slides of the ovary, uterine tube, and uterus
    - c. Label the appropriate histologic illustrations
3. Gametogenesis
    - a. Examination of prepared tissue slides illustrating gametogenesis
    - b. Diagram the steps in meiosis for the development of a mature ovum and a spermatozoa
4. Review the steps from fertilization, through the intrauterine development of the fetus, to the time of delivery using models prepared specimens, illustrations, and movies.

VI. Endocrine System

A. Units of Instruction

1. General
    - a. General functions of the endocrine glands as they relate to overall physiologic activity of the body
    - b. Glands composing the endocrine system
    - c. Brief survey of the embryologic development of the endocrine glands
2. Pituitary gland (hypophysis)
    - a. Neurohypophysis
        - i. Location and structure
        - ii. The hormones produced and their functions
    - b. Adenohypophysis
        - i. Location and structure
        - ii. The hormones produced and their functions
3. Thyroid gland
    - a. Hormones produced by the thyroid
    - b. Structure of the thyroid
        - i. Gross and microscopic anatomy
    - c. Thyroid physiology
        - i. The steps involved in the
            - (a) Formation and storage of thyroxine and triiodothyronine
            - (b) Release of thyroid hormone
            - (c) Systemic hormonal activity - include factors influencing each of these stages, e.g. TSH, TRF
        - ii. The effect of thyroid hormone on basal metabolism, general body growth, bone ossification, etc.
    - d. Introduction to pathologic conditions affecting the thyroid, e.g. hyperthyroidism (Grave's and Plummer's disease), primary and secondary hypothyroidism, acute and chronic thyroiditis, thyroid neoplasms
    - e. Thyroid medications
        - i. Major antithyroid medications and the stage in hormone production which they affect, e.g. proplythiouracil, thiocyanate
        - ii. Thyroid supplements, exogenous thyroid stimulating hormone
4. Adrenal gland
    - a. Location and structure of the adrenal glands
    - b. Adrenal cortex
        - i. Hormones produced by the adrenal cortex
        - ii. Factors affecting their release or suppression
        - iii. Functions of the hormones
    - c. Adrenal medulla
        - i. Hormones produced by the adrenal medulla
        - ii. Factors affecting their release or suppression
        - iii. Functions of the hormones
    - d. Effect of pituitary-adrenal hormonal axis
    - e. Pathologic conditions affecting the adrenal gland, e.g. Addison's disease, Cushing's disease, pheochromocytoma
5. Parathyroid glands
    - a. Location and structure of the parathyroid glands
    - b. The hormones produced by these glands; factors influencing their production, release, or suppression; their physiologic effects
    - c. Introduction to parathyroid gland pathology, e.g. hypoparathyroidism, hyperparathyroidism
6. Pancreas (islet cells)
    - a. Location and structure of endocrine functioning pancreas tissue
    - b. Hormones produced by this gland; factors influencing its production, release, and suppression; their physiologic effects.
    - c. Introduction to pancreatic endocrine pathology, e.g. islet cell carcinoma
7. The ovary, testes, and placenta are discussed in the section devoted to the reproductive system.
8. Introduction to nuclear medicine studies involving:
    - a. Pituitary gland, e.g. radioimmunoassay studies
    - b. Thyroid gland, e.g. throid imaging, thyroid uptake study, TSH stimulation study, radiobioassay for T-4, T-3.
    - c. Parathyroid glands, e.g. radioimmunoassay studies, parathyroid imaging study
    - d. Pancreas, e.g. radioimmunoassay study, pancreas imaging study
    - e. Adrenal gland, e.g. radioimmunoassay studies

VII. Muscular System

A. Units of Instruction

1. General
   a. Brief survey of the embryologic development of the muscular system
   b. Three types of muscles
2. Striated Muscle
   a. Structure of striated muscle
   b. Physiology of contraction and relaxing
   c. Voluntary muscles (examples)
3. Smooth muscle
   a. Structure of smooth muscle
   b. Physiology of contraction
   c. Involuntary muscles (examples)
4. Cardiac muscle
   a. Structure of cardiac muscle
   b. Physiology of contraction
5. Introduction to pathologic conditions affecting muscles, e.g. myositis ossificans progressiva

B. Laboratory Projects

1. Anatomy and Histology
   a. Examine histologic slide preparations of smooth, striated and cardiac muscle
      i. Diagram the tissues.
2. Physiology
   a. Class performance or demonstration of
      i. A single muscle contraction using a standard kymograph setup
      ii. "All or none" law using a frog and kymograph setup

VIII. Fluids and Electrolytes

A. Units of Instruction

1. General
   a. Importance of fluid and electrolyte balance
2. Composition of body fluids and homeostatic control
3. Regulation of electrolyte balance
4. Regulation of acid-base balance
   a. Factors involved in this balance and an introduction to how they function and interrelate. e.g. buffer system, respiratory mechanism, urinary mechanisms
5. Introduction to pathologic conditions relating to body fluids and electrolytes, e.g. heat stroke
6. Introduction to nuclear medicine procedure concerning fluid and electrolyte balance, e.g. total body water evaluation

B. Laboratory Projects

1. Experiment to demonstrate simple filtration
2. Experiment to demonstrate diffusion
3. Experiment to demonstrate osmosis

Texts and References

Boyd. Introduction to the Study of Disease

Chaffee and Greisheimer. Basic Physiology and Anatomy

Fallis and Ashworth. Textbook of Human Histology

Freeman and Bracegirdle. An Atlas of Histology

Frohse, Brodle, and Schlossberg. Atlas of Human Anatomy

Jacob and Francone. Structure and Function in Man

Jacob and Francone. Laboratory Manual of Structure and Function in Man

PERFORMANCE OBJECTIVES FOR ANATOMY, PHYSIOLOGY, AND PATHOLOGY I

I. CELLULAR AND TISSUE BIOLOGY

A. The student should be able to:

1. Define the term "cell." To be acceptable definition must include the fundamental structural and functional units of the body.
2. List the parts of a cell. To be acceptable, the list must include at least the following: cytoplasm, cell membrane, centrioles, Gogli body, mitochondria, nucleus, nuclear membrane, chromonemata, linin net, nucleolus, and genes.
3. Briefly state the functions of the cellular components listed in objective #2.
4. Name and describe two methods by which cell division is accomplished.
5. State the method of cell division by which the nonreproductive cells in the human body divide.
6. State the four phases of mitosis chronologically by phases.
7. Define permeability of cell membranes.
8. State the factors influencing cell membrane permeability. To be acceptable, these should include pore size, nature of substances that pass through, and changes in electrolyte concentrations that may take place during the process.
9. Define the term "tissue." To be acceptable, definition must state structure and function.
10. Name the four principle types of tissues in the human body.
11. Describe three principal differences among the different types of tissue.

II. SKIN

A. The student should be able to:

1. Describe the anatomy and function of skin.

II. SKIN (continued)

2. Describe the difference between the epidermis and the corium.
3. List 4 accessory organs of the skin, and state their function.
4. Describe the difference between sebaceous and sweat glands.
5. Describe the term "granulation response."

III. SKELETAL AND ARTICULAR SYSTEM

A. The student should be able to:

1. Identify three embryological germ layers. To be acceptable, response must include mesoderm, ectoderm, and endoderm.
2. State from which embryological germ layer the skeletal system derives.
3. Describe the classification of bones on the basis of their shape and structure.
4. List 5 bones included in the axial skeleton.
5. List 10 bones included in the appendicular skeleton.
6. Describe 2 methods of ossification.
7. Name substances necessary for bone formation and manufacture, including at least vitamin-B, calcium, carbonates, and phosphorous.
8. State the anatomical position and contiguous skeletal structures of the major bones of the body, and locate where various normal growth lines are to be found.
9. Describe the characteristics of the articular surfaces and the general types of joints found in the body.
10. Describe the clinical characteristics of the major neoplasms of bone, including the following:
    a. Metastatic-various patterns from various tumors
    b. Osteogenic sarcoma
    c. Ewing's sarcoma
    d. Lymphomas
    e. Multiple myeloma.

III. SKELETAL AND ARTICULAR SYSTEM (continued)

11. Identify three pathological conditions which may result in a positive joint scan.

12. Describe the evolution of bone scanning. To be acceptable, description must involve ^{85}Sr, ^{87m}Sr, ^{18}F, and ^{99m}Tc.

13. Describe the image characteristics that differentiate bone cysts from bone tumors.

14. Describe how the appearance of skeletal pathology on the X-ray differs from its appearance on the bone scan.

15. Describe the special care that may be required for the prevention of injury or fracture of bones at the site of pathological lesions and in the handling of the patient with a fracture at the site of pathological lesions.

IV. NERVOUS SYSTEM

A. The student should be able to:

1. State from what embryological germ layer the nervous system derives.

2. Describe the embryological development of the spinal cord. To be acceptable, the following stages of development must be included:

   a. Neural plate

   b. Neural groove

   c. Neural fold

   d. Neural tube.

3. List 3 types of neuroglial cells, To be acceptable, astrocytes, oligodendrocytes, and microglia should be included.

4. List 3 functions of neuroglial cells. To be acceptable, list must include support, protection, and nutrition.

5. Describe the basic nerve cell (neuron) including at least the following parts:

   a. Cell body

   b. Nucleus

   c. Cytoplasm

   d. Dendrites

   e. Axons .

IV. NERVOUS SYSTEM (continued)

6. State the function of the dendrites.

7. State the function of the axons.

8. Describe a synapse.

9. Describe the general physiologic process in which the nerve cell transmits its impulse.

10. Describe the anatomical components of the central and peripheral nervous systems.

11. State the anatomical features of the brain including the location, size, weight, shape, and a description of its lobulated structure.

12. State the general functions of the brain. To be acceptable, this must include the following functions:

    a. Regulatory center

    b. Seat of consciousness

    c. Seat of sensations

    d. Source of voluntary acts

    e. Seat of emotions

    f. Seat of higher mental processes.

13. Name at least 4 functions of the cerebellum.

14. Describe the anatomical features of the cerebrum including locations, size, shape, and descriptions of its lobulated structure and surface characteristics.

15. Name 4 lobes of the cerebrum.

16. Describe the anatomical location of each of the 4 lobes within the cerebrum.

17. Name at least 5 general functions of the cerebrum.

18. Describe the choroid plexuses including location, anatomy, the structure from which they form, and a description of their vascularity.

19. State the major function of the choroid plexuses.

20. State the major functions of the spinal cord.

IV. NERVOUS SYSTEM (continued)

21. Describe the general anatomic features of the meninges.

22. Describe the functions of the meninges.

23. Describe the characteristics of cerebro spinal fluid. To be acceptable, the description must specify the anatomic distribution, circulation, where it is formed, and where it re-enters the blood stream.

24. Describe the flow of blood through the brain in the correct chronological order including at least the flow through the vertebral and internal carotid arteries, circle of Willis, arterioles, capillaries, venules of the cranial cavity, venous sinuses, and internal jugular veins.

25. Describe in detail the blood-brain barrier. To be acceptable, the description must include the following points: close packing of cellular processes and vascular elements, lack of extra-cellular space, lack of perivascular space, the hindering of most metabolites from passing into the brain, comparison of blood-brain barriers of immature and fully developed central nervous systems, and importance of the blood-brain barrier in the diagnosis of disease states.

26. Describe the general nature, distribution, and behavior of tumors of the central nervous system. To be acceptable, the description must include:

    a. Tumors of the central nervous system

    b. Chordomas

    c. Ependymomas

    d. Oligodendrogliomas

    e. Astrocytomas (grades 1-4)

    f. Pinealoma

    g. Medulloblastomas

    h. Neuroblastomas

    i. Neurofibromas

    j. Meningiomas

    k. Hemangiomas

    l. lymphomas

    m. Mixed tumors

    n. Hypophyseal tumors

    o. Metastatic tumors.

IV. NERVOUS SYSTEM (continued)

27. Describe the difference between the brain scan, the cerebral radioisotope arteriogram, and the cisternogram.

28. Describe four clinical symptoms which often serve as indications for a brain scan.

29. Define the concept of target to nontarget in brain scanning.

30. Describe the use of perchlorate and atropine in brain scanning.

V. REPRODUCTIVE SYSTEM

A. The student should be able to:

1. Describe the gross anatomy and function of the male reproductive organs including the penis, prostate, and seminal vesicles.

2. Describe the microscopic anatomy of the male reproductive organs including the Sertoli cells, interstitial cells of Leydig, and the germinal epithelium.

3. Describe at least 5 functions of testosterone.

4. Describe the regulating mechanism of testosterone secretion.

5. Identify the embryological germ layer from which most of the reproductive system derives.

6. Describe the gross anatomy and function of the female reproductive organs including the vulva, vagina, uterus, uterine cervix, ovaries, and uterine (Fallopian) tubes.

7. Describe the microscopic anatomy and function of the female reproductive organs including the graafian follicles and layers of the uterine wall.

8. Name the two structures of the female ovaries which are the principle sources of the female sex hormones.

9. Name the principle groups of female sex hormones.

10. Name the three principle estrogens.

V. REPRODUCTIVE SYSTEM (continued)

11. Describe the effects of the estrogens including control of sexual growth and development, development of secondary sex characteristics, their role in the normal functioning of the genital system and changes involving body form, condition of skin, condition of mucous membranes, structure of skeleton, water balance, and metabolic activities.

12. Name the organ which regulates the secretion of ovarian hormones.

13. Identify the hormone responsible for stimulation of milk production in the mammary gland.

14. Describe the difference between mitosis and meiosis.

15. Describe the difference between genotype and phenotype.

16. Define the terms "chromosomes," "genes," and "DNA."

17. State steps in embryonic development from fertilization to delivery.

18. Define the normal site of placental implantation. To be acceptable, the answer must include that this is viewed anteriorly.

19. List the abnormal sites of placental implantation.

20. Define the term "ectopic pregnancy."

21. Define the term "placenta previa."

22. Describe the difference between the following:

    a. Marginal placenta previa
    b. Partial placenta previa
    c. Complete placenta previa.

23. Discuss nuclear medicine procedures related to the reproductive system, including radionuclide placentography, radionuclide placental imaging, and radioimmunoassay studies.

24. Describe a diagnostic procedure performed in the determination of placenta previa other than radioisotope placentography.

VI. ENDOCRINE SYSTEM

A. The student should be able to:

1. Define the term "hormone." To be acceptable, definition must include gland produced regulator carried in the blood stream.

2. Describe the general characteristics of the endocrine system.

3. Name the glands and organs included in the endocrine system. To be acceptable, these must include:

   a. Hypophysis cerebri
   b. Thyroid
   c. Parathyroid
   d. Adrenal
   e. Pancreas (organ)
   f. Duodenum (organ)
   g. Testes
   h. Ovaries
   i. Placenta (organ)

4. Identify the embryologic germ layer from which the endocrine system develops.

5. Name two principle factors which regulate the secretion of hormones.

6. Describe the general gross anatomy of the hypophysis cerebri.

7. State the general functions of the anterior lobe. To be acceptable, this must include: control of skeletal growth, growth and development of gonads, maturation of reproductive cells, and secretion of the milk by the mammary glands.

8. Describe the general functions of the posterior lobe. These must include the influence of blood pressure, and the stimulation effect upon smooth muscles, and the antidiuretic effect upon kidneys.

9. Name the hormones secreted by the anterior lobe of the hypophysis cerebri including growth promoting hormone (STH or HGH), thyrotropic hormone (TTH or TSH), gonadotropic hormones (FSH, ICSH, LTH), lactogenic hormone (LGH), and adrenocorticotropic hormone (ACTH).

VI. ENDOCRINE SYSTEM (continued)

10. Describe the effects of each of the hormones secreted by the anterior lobe on the hypophysis cerebri.

11. Name 2 hormones secreted by the posterior lobe of the hypophysis cerebri and describe the effects of each.

12. Specify 2 hormones secreted by the thyroid gland.

13. Describe 5 physiological effects of thyroid hormones. To be acceptable, response must include basal metabolism, body growth, growth and function of the nervous system, cardiac metabolism, and water and electrolyte balance.

14. State what the nuclear medical significance of Plummer's disease is.

15. Define the term "hypothyroidism."

16. Define the term "primary hyperthyroidism" (Grave's disease).

17. State the anatomical features of the adrenal glands including the following: size, shape, location, weight.

18. Describe the cortex of the adrenal glands.

19. Identify the embryologic tissue from which the cortex develops.

20. Describe the medulla of the adrenal gland.

21. Identify the embryologic tissue from which the medulla develops.

22. Describe the cortical functions of the adrenals. The description must include the regulation of the following: salt metabolism, water-electrolytic balance, muscular activity, reproductive activity, and kidney function.

23. Describe the medullary functions of the adrenal glands. The description must include the regulation of basal metabolism and carbohydrate metabolism and the initiation of certain physiologic responses.

24. Name 3 groups of hormones secreted by the adrenal cortex.

25. Explain the general functions of each group.

26. Name the 2 major secretions of the medulla of the adrenal glands.

VI. ENDOCRINE SYSTEM (continued)

27. Describe the effects of these hormones on blood pressure, respiration, stimulation of skeletal muscles, basal metabolism rate, and stimulation of carbohydrate metabolism.

28. Describe the physiologic difference between Addison's and Cushing's disease.

29. Describe the location of the parathyroid glands.

30. Identify the hormone secreted by the parathyroid glands.

31. Describe the regulatory function of the parathyroid glands.

32. Identify one factor responsible for parathyroid stimulation.

33. Describe the anatomical features of the islets of Langerhans including location, number, where within the pancreas they are most numerous, and a description of their organization in the pancreas.

34. Identify two types of islet cells as well as the hormone each secretes.

35. Explain the difference between diabetes mellitus, and diabetes insipidus.

36. Identify a pathologic condition based on disease of pituitary growth hormone production which may be studied with radioisotope methods.

37. List five diseases of the thyroid gland which may be studied through radioisotopic methods and five radioisotopic thyroid tests.

38. Explain why high quality parathyroid scans are difficult to obtain.

39. Identify the element most commonly used in isotopic studies of the adrenal glands.

VII. MUSCULAR SYSTEM

A. The student should be able to:

1. Identify the embryologic germ layer from which the muscular system develops.

2. Describe the difference in structure of smooth and cardiac muscle.

VII. MUSCULAR SYSTEM (continued)

3. Describe oxygen debt.
4. Describe the physiology of smooth and cardiac muscle contraction.
5. Give 3 examples of each voluntary and involuntary muscle.

VIII. FLUIDS AND ELECTROLYTES

A. The student should be able to:

1. List the organs involved in the acid-base balance and briefly describe the role of each.
2. Describe what happens to the electrolyte balance when one drinks a lot of water.
3. Identify a pathologic condition relating to body fluids and electrolytes.
4. Identify the plasma ions which may be studied radioisotopically in the investigation of disturbances in fluid balance.

COMMUNICATION SKILLS

Hours Required

Class, 3

Course Description

COMMUNICATION SKILLS is designed to assist the nuclear medicine technician develop skills in research, reading, writing, and talking. All course assignments should require the student to respond with some oral or written communication. The students will be required to use reference books to correct any errors in their work. For students who have not mastered the basic rules of grammar and usage, programmed texts are available for independent study.

Major Divisions		Semester Class Hours
I.	What is Communications?	2
II.	Using the Library as a Source of Technical Information	5
III.	Reading Technical Reports and Papers	8
IV.	Written Communications	16
V.	Oral Communications	14
	Total	45

I. What is Communications?

A. Units of Instruction

1. Various kinds
    a. Mass (TV, radio, etc.)
    b. Intergroup
    c. Interpersonal (one-to-one)
2. Purposes of communications
    a. Exposition
    b. Persuasion
    c. Information
    d. Inquiry
    e. Entertainment
3. Ranges of styles and vehicles
    a. Written communications
        i. Informal
        ii. Formal
        iii. Books
        iv. Articles
        v. Letters
        vi. Memos
        vii. Advertisements
    b. Oral communciations
        i. Lectures
        ii. Group meetings
        iii. Person-to-person
    c. Visual communications
        i. Pictures
        ii. Movies
        iii. TV

II. Using the Library as a Source of Technical Information

A. Units of Instruction

1. Library classification systems
2. How to use card catalog and the classification system
3. Dictionaries, encyclopedias, and manuals
4. Guides to books and periodicals
5. Indexes to periodicals
6. Government publications
7. Research on nuclear medicine problems

III. Reading Technical Reports and Papers

A. Units of Instruction

1. Analysis of various forms for reports and papers
    a. Laboratory experiments
    b. Reports of experimental procedures
    c. Journal articles
2. Review of various journals the nuclear medicine technician will need for reference, review, and updated information.
3. The scientific method
    a. Meaning of the method
    b. Characteristics of the scientific method
    c. Essentials of scientific style
    d. Importance of accuracy and intellectual honesty in observation and recording
    e. Legal importance of recorded data and log books
4. Reading the paragraph
    a. Locating the main idea
    b. Ferreting out facts
    c. Drawing inferences
    d. Sensing tone
    e. Noting the structural organization
    f. Skimming and scanning for specifics
    g. Following pronoun references
    h. Making conclusions
    i. Following guide words
5. Skimming
    a. Purpose of skimming
    b. Skimming the whole
    c. Skimming an article
    d. Previewing a book
6. Scanning
    a. Scanning skills
    b. Difference between skimming and scanning
7. Intensive reading: Study type reading
    a. Using the SQ3R method
        i. Survey
        ii. Question
        iii. Read
        iv. Review
        v. Recall
    b. Difference between intensive reading and other types of reading skills

IV. Written Communications

A. Units of Instruction

1. Using reference books to correct grammar and spelling mistakes
2. Organizing written communications
    a. Sentences
    b. Paragraphs
    c. Purpose of topic sentences
    d. Unity
    e. Sticking to the topic
    f. Considering the audience
    g. Determining the purpose of the communication
3. The business letter
    a. Complaints
    b. Inquiry
    c. Job hunting
    d. Information
4. Writing memoranda
5. Informal reports on the job

V. Oral Communications

A. Units of Instruction

1. Listening
    a. Reasons for listening
        i. For facts
        ii. To analyze facts and ideas
        iii. To evaluate facts and ideas
        iv. For elaboration
        v. For entertainment
        vi. To improve speaking skills
2. Public speaking
    a. Characteristics of a good speech
    b. Selecting a subject
    c. Defining your purpose
    d. Organizing your speech
    e. Developing your speaking skills
        i. voice
        ii. actions
        iii. avoiding common errors of speakers
3. Group work
    a. Functions of a leader in a small group
    b. Questions and answers, how to use that time effectively
    c. Control of group process
    d. Sensitivity to needs of the group and individuals

4. One-to-one communications
    a. Value of listening to the other person
    b. Understanding another's point of view
    c. Making a point clearly
    d. When to follow oral communications with memoranda
5. Communications problems in the hospital environment
    a. The patient
    b. The supervisor
    c. Physicians and nurses
    d. Colleagues
    e. Equipment suppliers

Texts and References

Albaugh. English: A Dictionary of Grammar and Structure

Baird and Knower. Essentials of General Speech

Barton, Reference Books: A Brief Guide for Students and Other Users of the Library

Berlo. The Process of Communication

Brown. Efficient Reading

Campbell and Helpler. Dimensions in Communications.

Canavan. Effective English: A Guide for Writing

Capp. How to Communicate Orally

Carter et al. Effective Reading for College Students

Case and Vardaman. Mature Reading and Thinking

Cowan and McPherson. Plain English, Please

Crouch and Zetler. Guide to Technical Writing

Gaum, Graves, and Hoffman. Report Writing

Hutchins. Introduction to Reference Work

Judson. The Techniques of Reading

Leedy. Read with Speed and Precision

McCall and Cohen. Fundamentals of Speech

Oliver et al. Communicative Speaking and Listening

Sherbourne. Toward Reading Comprehension

Shores. Basic Reference Sources

Thompson. Fundamentals of Communication

Winschell. Guide to Reference Books

Young and Symonik. Practical English, Introduction to Composition

Zelko and Dance. Business and Professional Speech Communications

Handbooks

Buckley and McAvory. American College Handbook of English Fundamentals

Fowler. A Dictionary of Modern English Usage

Nicholson. A Dictionary of American-English Usage

Perrin and Smith. Handbook of Current English

SEMESTER 2

Radiation Safety & Radiation Biology

Nuclear Instrumentation I

Anatomy, Physiology & Pathology II

Chemistry for the Health Sciences

Medical Terminology

RADIATION SAFETY AND RADIATION BIOLOGY

Hours Required

Class, 3

Course Description

RADIATION SAFETY AND RADIATION BIOLOGY acquaints the student with the fundamentals of handling radioactive materials safely, emergency procedures involving radioactive spills, contamination, etc., plus proper record keeping. Although there is no laboratory for this course, radiation protection instrumentation is covered in NUCLEAR INSTRUMENTATION I which is given concurrently. The radiation biology portion of this course reinforces the concept of safe handling of radioactive materials by explaining what happens to the body following exposure to various dose levels.

Major Divisions

		Semester Class Hours
I.	Units of Radiation Exposure and Dose	3
II.	Guidelines for Radiation Protection	1
III.	Safe Handling of Radioactive Material	6
IV.	Radiation Surveys	2
V.	Emergency Management and Decontamination Techniques	3
VI.	Management of Radioactive Waste	3
VII.	Records of Radionuclide Accountability	2
VIII.	Radiobiology of the Cell	10
IX.	Radiation Genetics	2
X.	Local and Systematic Reactions	3
XI.	Late Effects	4
XII.	Critical Organs and Dose Calculations	6
	Total	45

I. Units of Radiation Exposure and Dose

A. Units of Instruction

1. Rad
2. Rem and dose equivalent
3. RBE and quality factor
4. Roentgen
5. Curie and specific activity
6. Relationship of activity (Curies) to radiation exposure (Roentgen)

II. Guidelines for Radiation Protection

A. Units of Instruction

1. NCRP recommendations
2. AEC regulations and licensing
3. State regulations
4. Local regulations
5. Hospital regulations - Hospital manual

III. Safe Handling of Radioactive Material

A. Units of Instruction

1. Reduction of radiation exposure
    a. Time
    b. Distance
    c. Shielding
2. Laboratory design - restricted area
3. Laboratory equipment and supplies
    a. Work area materials
    b. Pipetting procedure
    c. Selection of shield
    d. Protective clothing
4. Receipt of radionuclides
    a. Determination of contamination
    b. Verification of assay and concentration
    c. Correct procedures regarding use of radionuclides
5. Hazards
    a. Preventive measures limiting internal exposure
    b. Methods detecting internal emitters
6. Personnel monitoring records
    a. Acceptable level of exposure
    b. Unacceptable level of exposure

IV. Radiation Surveys

A. Units of Instruction

1. Area surveys
2. Wipe tests
3. Leak tests
4. Acceptable and unacceptable levels of radiation
5. Records
6. Personnel monitor records
    a. Routine
    b. Overexposure

V. Emergency Management and Decontamination Techniques

A. Units of Instruction

1. Operating procedures (hospital-manual)
    a. Spills
    b. Precautions for patients having received radionuclides
2. Types of contamination
    a. Minor spill
    b. Major spill

3. Determination of human contamination
    a. Monitoring procedure - whole body counters
    b. Decontamination procedures
4. Determination of area contamination
    a. Monitoring procedure
    b. Decontamination procedures
5. Record and reporting procedures

VI. Management of Radioactive Waste

A. Units of Instruction

1. Regulations governing waste management
    a. Government
    b. Hospital
2. Handling and storage of radioactive waste material
3. Methods of radioactive waste disposal
    a. Solid waste
    b. Liquid waste
    c. Gaseous waste
4. Records

VII. Records of Radionuclide Accountability

A. Units of Instruction

1. Records of receipt of radionuclides
2. Records of use and storage of radionuclides
    a. Transfer of radionuclides
3. Records of disposal of radionuclides
4. Inventory procedures - radionuclide accountability
    a. Maximum permissible possession limit

VIII. Radiobiology of the Cell

A. Units of Instruction

1. The cell structure and function
    a. Cell
        i. Characteristics
        ii. Content and function
        iii. Growth and reproduction
    b. Cells to tissues
    c. Specialized tissue to organ
    d. Organ to organ systems
2. Linear energy transfer
3. Radiobiologic effects
    a. Direct and indirect action
    b. Interaction of ionizing radiation with water
        i. Formation of free radicals
        ii. Reaction with free radicals
    c. Ionization of other cellular components
    d. Influence of hydration and dehydration on radiosensitivity
    e. Target theory
4. Differential sensitivity of cells to radiation
    a. Cell cycle
        i. Class I cells
        ii. Class II cells
        iii. Class III cells
        iv. Class IV cells
    b. Law of Bergonie and Tribondeau
    c. Factors affecting radiosensitivity
    d. Radiosensitivity and radiocurability of tumors
    e. Radiosensitizing compounds
    f. Radioprotection compounds
5. Interpretation of survival data
    a. Survival data and survival curves
    b. Mean lethal dose
6. Factors influencing survival of irradiated cells
    a. RBE and oxygen effect
    b. Cellular repair

IX. Radiation Genetics

A. Units of Instruction

1. Genetic code - DNA molecule
    a. Arrangement of code
    b. Determination of organism characteristics
    c. Genetic mutation
        i. Point mutation
        ii. Chromosomal aberrations
2. Effect of induced motation on large population
    a. Genetic load
    b. Doubling dose
    c. Dominant and recessive mutations
    d. Dependency on LET frequency

X. Local and Systemic Reactions

A. Units of Instruction

1. Immediately lethal effects
    a. Acute effects
    b. Late effects
2. LD 50/30
3. Tissue or organ radiosensitivity
4. Radiation syndromes
    a. Bone marrow syndrome
        i. Manifestations
        ii. Histologic changes
        iii. Cytologic changes
        iv. Latent Period
        v. Blood counts
        vi. Infection
    b. Gastrointestinal syndrome
        i. Manifestations
        ii. Degenerative changes in the lining of small intestine
        iii. Histological changes
        iv. Regeneration
        v. Large intestine
        vi. Effects on cell renewal
            (a) Mitosis
            (b) Precursor cells
        vii. Fluid and electrolytes
        viii. Infections

c. Central nervous system syndromes
i. Lethal dose rate
ii. Manifestations
iii. Histologic and inflammatory changes
iv. Cytologic changes
v. Results of vascular damage
vi. Cause of death

XI. Late Effects

A. Units of Instruction

1. Life span shortening

2. Sterility

3. Increased tumor incidence
a. Radiation induced leukemia
b. Radiation induced cancers

4. Radiation cataractogenesis

5. Growth and developmental effects on organism
a. Radiosensitive embryonic cells
i. Differentiation
ii. High rate of mitotic activity
iii. Limited numbers of cells
b. Lethality and production of anomalies
c. Effects in later generations

XII. Critical Organs and Dose Calculations

A. Units of Instruction

1. Factors influencing absorbed dose from internal radionuclide
a. Concentration
b. Time
c. Type of radiation
d. Energy emitted
e. Fraction absorbed

2. Critical Organs
a. Factors determining critical organs for a given radionuclide
b. Critical organs for Nuclear Medicine examinations

Texts and References

Dalrymple, Gaulden, Kollmorgen, and Vogel. Medical Radiation Biology

Early, Razzak, and Sodee. Textbook of Nuclear Medicine Technology

National Bureau of Standards Handbook #92 "Safe Handling of Radioactive Materials"

Pizzarello and Witcofski. Basic Radiation Biology

Pizzarello and Witcofski. Medical Radiation Biology

Quimby, Feitelberg, and Gross. Radioactive Nuclides in Medicine and Biology

RCA. Atomic Radiation

Shapiro. Radiation Protection, A Guide for Scientists and Physicians

PERFORMANCE OBJECTIVES FOR RADIATION SAFETY AND RADIATION BIOLOGY

I. UNITS OF RADIATION EXPOSURE AND DOSE

A. The student should be able to:

1. Define the term "curie."
2. Define the term "specific activity."
3. Define the term "specific gamma ray constant."
4. Define the terms "RBE, Rem, and dose equivalent."
5. Define the terms "particle energy" and "photon energy."
6. Define the unit "roentgen."
7. Define the unit "Rad."
8. Explain the difference between the unit of radiation exposure, roentgen and the unit of absorbed dose, Rad.

II. GUIDELINES FOR RADIATION PROTECTION

A. The student should be able to:

1. Identify the agencies responsible for control of radiation exposure. To be acceptable, these must include the AEC, FDA, and state agencies where applicable.
2. Define maximum permissible levels of radiation.
3. Describe maximum permissible levels of radiation for individual over 18 in one calendar quarter due to occupational exposure with reference to whole body, hands, forearm, and skin.
4. Describe maximum permissible levels of radiation for individuals over 18 in one calendar quarter due to nonoccupational exposure with reference to whole body, hands, forearm, and skin.
5. Describe maximum permissible levels of radiation for individuals under 18 in one calendar quarter due to nonoccupational exposure with reference to whole body, hands, forearm, and skin.
6. Define the term "significant contamination" with reference to Beta and Gamma emitters.
7. Define the term "restricted area."
8. Describe the amount of radioactivity requiring the posting of the following radiation signs:
   a. Radiation Area) dose rate reference
   b. High Radiation Area)
   c. Caution: Radioactive Materials) quantity reference

II. GUIDELINES FOR RADIATION PROTECTION (continued)

9. Describe the conditions requiring a radioactive materials label on a container.
10. Describe the information to be put on the radioactive materials label.

III. SAFE HANDLING OF RADIOACTIVE MATERIAL

A. The student should be able to:

1. Describe the basic concepts of time, distance, and shielding.
2. Describe the procedures for limiting internal exposure by means of inhalation, ingestion, and absorption.
3. Describe the proper procedures to follow on receipt of a shipment of radioactive material.
4. Describe the proper procedures to follow if a shipment is determined to be contaminated.
5. Describe the proper procedures to follow in verifying the assay and concentration of a radioactive material.
6. Describe the proper procedures to follow in diluting, sterilizing, or performing other procedures on a radioactive material.
7. Describe the type, use, and disposal of work area materials used during the handling of radioactive materials.
8. Describe the type, use, and disposal of protective clothing used during the handling of radioactive materials.
9. Discriminate between correct and incorrect procedures for pipetting.
10. Describe the conditions which determine the selection of type and thickness of shield used with different radioisotopes.
11. Describe methods for detecting the inhalation, ingestion, or absorption of an internal emitter.

IV. RADIATION SURVEYS

A. The student should be able to:

1. Define radiation survey for:
   a. External exposure measurement
   b. Contamination check.

IV. RADIATION SURVEYS (continued)

2. Demonstrate the proper selection of a method for a given radiation survey.
3. Discriminate between unacceptable and acceptable levels in external exposure measurement in a restricted area.
4. Discriminate between acceptable and unacceptable levels in external exposure measurement in an unrestricted area.
5. Distinguish between acceptable and unacceptable levels of contamination using a wipe test.
6. Define the areas to be monitored in a nuclear medicine facility area survey.
7. Describe the methods of area survey for the following radiation monitors:
   a. GM radiation monitor
   b. Ionization chamber
   c. Film Badges
   d. TLD dosimeters.
8. Describe the use of the following radiation monitoring equipment for checking the contamination of objects:
   a. GM radiation monitor
   b. Wipe test.
9. Describe the conditions under which unacceptable contamination levels require emergency management procedures.
10. Describe the procedures for recording results of area surveys.

V. EMERGENCY MANAGEMENT AND DECONTAMINATION TECHNIQUES

A. The student should be able to:

1. Describe in the correct sequential order the procedures to be followed in case of major or minor spill of a given radioisotope.
2. Determine if the items of a checklist in a room containing selected surface tops, clothing, shoes, gloves, monitoring equipment are contaminated.
3. Demonstrate decontamination procedures using appropriate monitoring equipment, given that all of the items specified in objective #2 are contaminated.
4. Demonstrate decontamination procedures, using a mannequin representing the patient, appropriate decontamination materials, monitoring equipment, and information that the patient's hands and clothing are contaminated.

V. EMERGENCY MANAGEMENT AND DECONTAMINATION TECHNIQUES (continued)

5. Describe precautions to be taken for therapy patients returning to the hospital ward with more than 30 mCi of a given radioisotope.
6. Describe precautions to be taken for patients returning to the hospital ward with less than 30 mCi of a given diagnostic radioisotope.
7. Describe precautions to be given to outpatients leaving the nuclear medicine laboratory with less than 30 mCi of a given diagnostic radionuclide.

VI. MANAGEMENT OF RADIOACTIVE WASTE

A. The student should be able to:

1. Define the term "radioactive waste."
2. Describe the methods for the handling and storage of radioactive waste.
3. Describe the methods for the disposal of radioactive solid waste. To be acceptable, the description must include the following procedures:

   Procedures Checklist

   a. Determine amount of activity
   b. Label the isotope amount and the date
   c. Determine type of waste, i.e., combustible or noncombustible
   d. Determine the total mass or volume
   e. Communicate with the health physicist concerning the disposal of solid radioactive waste
   f. Record the nuclide, amount of activity, method of disposal, date, and compound.

4. Describe the procedures for the disposal of radioactive liquid waste via the drainage system. To be acceptable, the description must include the following procedures:

   Procedures Checklist

   a. Determine amount of activity or concentration
   b. Determine volume
   c. Record disposal date, nuclide, amount of activity, and compound.

5. Describe the procedures for disposal of solid combustible waste via the incinerator.

6. Describe the procedures for disposal of gaseous waste. To be acceptable, the description must include the following procedures.

VI. MANAGEMENT OF RADIOACTIVE WASTE (continued)

Procedures Checklist

- a. Determine amount of activity, volume, and concentration
- b. Determine permissible levels of disposal
- c. Consult with health physicist concerning the disposal method
- d. Record nuclide, compound, date, amount of activity, and method of disposal.

7. Describe the role of radioactive decay in waste management.

VII. RECORDS OF RADIONUCLIDE ACCOUNTABILITY

A. The student should be able to:

1. Define the term "radionuclide accountability."
2. Describe the tasks required to satisfy AEC and/or state radionuclide accountability regulations.
3. Describe the role of radionuclide decay in radionuclide accountability.
4. Describe the data required when ordering a radionuclide.
5. Describe the data required when recording the receipt of a radionuclide.
6. Describe the data required when recording the use of a radionuclide.
7. Describe the data required when recording the disposal of a radionuclide.
8. Describe the procedures and data required for transfer of a radionuclide from one licensee to another.
9. Describe the significance of maximum permissible possession limit.

VIII. RADIOBIOLOGY OF THE CELL

A. The student should be able to:

1. Define the terms: cell, tissue, organ, endocrine, exocrine.
2. Identify 5 characteristics of living organisms.
3. Describe 2 functions of 3 types of the tissues.
4. List the components of the cell and the function of each.
5. List 2 functions of each organ and organ system.
6. List the organs that comprise each organ system.

VIII. RADIOBIOLOGY OF THE CELL (continued)

7. List the different radiations. (An acceptable answer should include a, B^+, B^-, γ, X.)
8. List the mass and charge of each of the above.
9. Describe the interactions of the above radiations with matter.
10. Define the term "Linear Energy Transfer" and state its relationship to differences in particle mass and charge.
11. Describe direct and indirect action of ionizing radiation on the cell and compare their relative importance in production of damage.
12. Write the basic equations for the production of free radicals caused by ionizing radiation interacting in cellular water.
13. Describe how these free radicals produce damage in other more important "key" molecules such as DNA.
14. List the 4 stages of the cell division and compare their relative radiosensitivities.
15. Discuss progression and division delay after cell irradiation.
16. Describe evidence which supports the concept of repair of intraceullular damage.
17. List the factors which determine the relative radiosensitivities of tissues (Law of Bergonié and Tribondeau).

IX. RADIATION GENETICS

1. Describe how the genetic information or code is arranged on DNA molecules.
2. Describe the role of the gene in determining the characteristics of the individual.
3. Define the term "genetic mutation."
4. Distinguish between the mechanisms of point mutations and chromosomal aberrations.
5. Discuss the effect of radiation induced genetic mutations upon large populations including such concepts as genetic load, doubling dose, etc.

X. LOCAL AND SYSTEMIC REACTIONS

A. The student should be able to:

1. Describe acute effects of radiation. Correct response

X. LOCAL AND SYSTEMIC REACTIONS (continued)

will include the gastrointestinal syndrome, the bone marrow syndrome, and the central nervous system syndromes.

2. Define the term "LD 50."

XI. LATE EFFECTS

A. The student should be able to:

1. Distinguish between acute and late radiation effects.
2. List the most important later effects of radiation, i.e.,
   a. Impaired fertility
   b. Induction of cancer and leukemia
   c. Life shortening
   d. Cataracts.
3. Relate late radiation effects to dose levels.
4. List the factors related to high radiosensitivity of the embryonic stage. To be acceptable, the answer must include the following:
   a. Embryonic cells are differentiating
   b. Embryos have high rates of miotic and mitotic activity
   c. Early embryos are composed of relatively few cells.
5. Describe the relationship between stage of embryonic development and the abnormality produced.

XII. CRITICAL ORGAN AND DOSE CALCULATIONS

A. The student should be able to:

1. Define the term "absorbed dose."
2. List the four factors that influence the absorbed dose from an internal nuclide:

   a. Concentration
   b. Time
   c. Type of radiation and energy emitted
   d. Fraction absorbed.
3. Elaborate on the factors that influence each of the above:

   a. Concentration - activity per mass
   b. Time - biological halflife
      physical halflife
   c. Energy emitted - B^-, B^+, X, and γ
   d. Fraction absorbed.
4. Define the term "critical organ."

XII. CRITICAL ORGAN AND DOSE CALCULATIONS (continued)

5. Describe the factors that determine which is the critical organ for a given isotope.
   a. Concentration of nuclide (which organs)
   b. Radiosensitivity of the organ(s)
   c. Effective halflife of the nuclide in the organ(s)
   d. Whether or not the organ is essential
   e. Dose to the tissues along administration - excretion pathway.
6. List the critical organ for those isotopes used most often in nuclear medicine laboratories and explain why, based on objective #5.

NUCLEAR INSTRUMENTATION I

Hours Required

Class, 3; Laboratory, 3

Course Description

Upon completion of NUCLEAR INSTRUMENTATION I the student should be able to operate and calibrate radiation protection instruments and dose calibrators. He should also be able to name and describe the functions of each of the electronic modules in a single-channel pulse height analyzer.

The sequencing of main topics is recommended for integration with RADIATION SAFETY AND BIOLOGY, which is given concurrently.

Major Divisions

		Semester	
		Class Hours	Lab Hours
I.	Gas-filled Detectors	3	3
II.	Area and Personnel Monitoring Devices	9	12
III.	Scintillation and other Detectors	3	0
IV.	Scintillation Detection System Components	12	15
V.	Liquid Scintillation Counters	3	3
VI.	Counting Efficiency	3	3
VII.	Theory of Statistics of Counting	6	3
VIII.	Application of Statistics to Counting Data	6	3
	Total	45	45

I. Gas-filled Detectors

A. Units of Instruction

1. Ionization counters
2. Proportional counters
3. Geiger counters

B. Laboratory Projects

1. Given a Geiger counter determine the counting rate variation with voltage.

II. Area and Personnel Monitoring Devices (Theory of operation, calibration, and use)

A. Units of Instruction

1. Film badge
2. Pocket dosimeter (ionization type)
3. Thermoluminescent dosimeter
4. Review of other detection instruments based on collection

B. Laboratory Projects

1. Given a gamma source and a G-M detector and scaler, determine the effect of distance from a radioactive source on the intensity of its gamma radiation.
2. Given a gamma source, scintillation detector or G-M tube, scaler, and 1mm lead sheets, determine the thickness of lead that will reduce the intensity of a beam of gamma rays to one half its original value.
3. Given the same materials as in 2, but with two or more gamma sources, quantitatively measure and compare the gamma ray energies.
4. Given a source mixed with grease and applied to cloth, test the efficiency of several detergents for removing the grease.

III. Scintillation and other Detectors

A. Units of Instruction

1. Crystals (flat-faced and well type)
2. Plastic scintillators
3. Liquid scintillators
4. Semi-conductor detectors

IV. Scintillation Detection System Components

A. Units of Instruction

1. Photomultiplier tube
2. Amplification, charge collection, and pulse shaping
3. Pulse height analysis and spectrometry
4. Recorders and data indication
   a. Scalers
   b. Ratemeters
   c. Strip chart recorders
   d. Others

B. Laboratory Projects

1. Given manuals for a well counter and surface probe, draw a block diagram and describe the functions of each block.
2. Given a scintillation counter, plot the integral spectra of several radioisotopes, and determine the effect of the gamma energy on the shape of the curves. Also determine how to calculate the best operating voltage.
3. Given a scintillation spectrometer and input pulse generator, adjust each of the controls on the single-channel analyzer and note its effect.
4. Given a scintillation spectrometer and known gamma emitting sample such as ^{137}Cs obtain the differential spectrum.

5. Given a scintillation spectrometer and unknown gamma emitting sample, calibrate the energy scale with ^{137}Cs, and obtain the photopeak energy of the unknown and identify it.

V. Liquid Scintillation Counters

A. Units of Instruction

1. Simplified coincident circuit

2. Quenching correction

B. Laboratory Projects

1. Given a well counter or 2-channel liquid scintillation counter, measure carbon-14 and tritium activity in the same solution.

VI. Counting Efficiency

A. Units of Instruction

1. Definition

2. Influencing factors
   a. Geometry
   b. Absorption
   c. Scatter

3. Effect on results

B. Laboratory Projects

1. Given a crystal scintillation counter and several gamma sources of different energies between 100 Kev and 500 Kev, vary the source to detector distance and calculate the geometric and crystal counting efficiency factors.

VII. Theory of Statistics of Counting

A. Units of Instruction

1. Introduction to statistics
   a. Sources of uncertainty in physical measurements
      i. Systematic errors
      ii. Random errors
2. Frequency distribution and statistical parameters
   a. Binomial
   b. Poisson
   c. Gaussian and normal
   d. Mean
   e. Variance and standard Deviation
   f. Confidence intervals

B. Laboratory Projects

1. Given an equation with data and the probable error for each term, calculate the probable error for the resultant.

VIII. Application of Statistics of Counting Data

A. Units of Instruction

1. Calculation of standard deviation for total count, total count rate, net count, and net count rate

2. Fractional standard deviation and percent error

3. Chi-square test for goodness of fit

4. Minimum detectable activity

5. Counting statistics in ratemeters and recorders

6. Figure of merit for optimizing window width

B. Laboratory Projects

1. Given a scintillation detector or G-M tube and scale, take 40 1/2 minute readings, plot, and obtain the mean, the standard deviation, and the fractional standard deviation.

2. Solve applied problems which test for statistical significance.

Texts and References

Beck and Gottschalk. Fundamental Problems in Scanning

Behrens, King, and Carpenter. Atomic Medicine

Blahd. Nuclear Medicine

Chase and Rabinowitz. Principles of Radioisotope Methodology

Croll and Brady. Recent Advances in Nuclear Medicine

Croll, Brady, Tatem, and Honda. Clinical Dynamic Function Studies with Radionuclides

Early, Razzak, and Sodee. Textbook of Nuclear Medicine Technology

Freeman and Johnson. Clinical Scintillation Scanning

Hine. Instrumentation in Nuclear Medicine, Vol. 1

International Atomic Energy Agency. Medical Radioisotope Scanning, Vol. 2

International Atomic Energy Agency. Medical Radioisotope Scintigraphy, Vol. 1

Maynard. Clinical Nuclear Medicine

Price. Nuclear Radiation Detection

Quimby, Feitelberg, and Gross. Radioactive Nuclides in Medicine and Biology

Simmons. A Training Manual for Nuclear Medicine Technolgists

Southeastern Chapter of Nuclear Medicine. Continuing Education Lectures; A Review of Nuclear Medicine

Wagner. Principles of Nuclear Medicine

PERFORMANCE OBJECTIVES FOR NUCLEAR INSTRUMENTATION I

I. GAS-FILLED RADIATION DETECTORS

A. The student should be able to:

1. Describe the components of a gas-filled detector. The description should include the function of each component of a gas-filled detector.

2. Describe the production and collection of ion pairs.

3. Diagram the pulse height vs voltage curve for gas-filled detectors. The diagram should include the following regions in their proper places: re-combination, ionization, proportional, nonproportional, Geiger-Mueller, and continuous discharge regions.

4. Explain what happens in the production of a pulse in each of the regions specified in objective #3.

5. Compare ionization counters, proportional counters, and Geiger counters in regard to advantages, disadvantages, operating voltage, and applications to radiation detection. The comparison should include specification of which detector is best for certain radiation types and energies.

6. Explain the advantage of a current-measuring ionization chamber instrument over a pulse-counting instrument for assaying millicurie-level amounts of radioactivity.

II. AREA AND PERSONNEL MONITORING DEVICES

A. The student should be able to:

1. Describe the components and operation of the following instruments:
   a. GM radiation survey meter
   b. Ionization chamber survey meter.

2. Describe the procedures used to check monitoring instrument reliability.

3. Discriminate between a functioning and a malfunctioning instrument in the following categories:
   a. GM radiation survey meter
   b. Ionization chamber survey meter.

4. Describe the components of a film badge and its use in a radiation survey.

II. AREA AND PERSONNEL MONITORING DEVICES (continued)

5. Describe the components of a TLD monitor and its use in a radiation survey.

6. Describe the materials and instrumentation used to perform a wipe test.

7. Determine the efficiency of a given radiation survey instrument or counting system.

8. Select the proper survey instrumentation to measure:
    a. A given type and energy of radiation
    b. A given exposure range.

9. Calibrate a radiation survey instrument for both external beta and gamma emissions.

B. The student should be able to:

1. Describe the purpose of the following personnel monitoring devices:
    a. GM radiation monitor
    b. Ionization chamber radiation monitor
    c. Film badges
    d. TLD dosimeters.

2. Describe the data required when recording the results of personnel monitoring.

3. Describe the procedures and data required when reporting an overexposure.

4. Describe those procedures involved in routine personnel monitoring.

5. Demonstrate the proper selection of a personnel monitoring instrument for a given type and energy of radiation.

III. SCINTILLATION AND OTHER DETECTORS

A. The student should be able to:

1. Describe the series of basic events by which the energy by a detected gamma (or X-ray) photon is transformed proportionally to electrical pulses which can be selectively analyzed and counted on the basis of the original gamma (or X-ray) energy.

III. SCINTILLATION AND OTHER DETECTORS (continued)

2. Describe the necessary properties of a good solid crystal scintillator including high density, high atomic number, high luminescent output at useful wavelengths.

3. Describe the extent to which NaI (Tl) possesses these properties, but also the disadvantages of fragility and hygroscopic nature.

4. Describe qualitatively the light-producing process, including the role of the thallium activator.

5. Describe the important parameters of light collection from the crystal, including effects of surface polish, reflector materials, and optical coupling media.

6. Describe operation of detectors other than NaI(Tl).

7. Describe the operation of semiconductor detectors, as well as the advantages and disadvantages of such detectors for clinical use.

IV. SCINTILLATION DETECTION SYSTEM COMPONENTS

A. The student should be able to:

1. Describe the function, construction, and operational properties of a photomultiplier tube including photocathode, dynodes and anode, and the effect of high voltage on pulse size.

2. Describe qualitatively pulse shaping in terms of charge collection (integration) and pulse clipping (differentiation).

3. Describe the operation of energy-selective counting systems employing scintillation detectors.

4. State *why* energy-selective counting is used clinically. It should be stated that it is necessary to avoid counting scattered radiation.

5. Describe the effect of amplifier gain on pulse size.

6. Describe energy-selective counting by pulse-size measurement (pulse height analysis). To be acceptable, the definition must include concepts of lower and upper level discriminators with appropriate anti-coincidence circuitry.

7. Describe spectrometry and pulse height spectra and diagram a typical gamma ray pulse height spectrum. The phenomena

IV. SCINTILLATION DETECTION SYSTEM COMPONENTS (continued)

responsible for each region must be described and correlated with gamma (or X-ray) photon energy. To be acceptable, internal effects must be differentiated from extrinsic effects.

8. Outline the proper procedure for "calibrating" or determining proper photomultiplier voltage and amplifier gain for an energy-selective system using a single-channel analyzer. To be acceptable, window widths for the calibration procedure and for routine counting should be described as well as means of their determination.

9. Describe a crude means of determining "line width" (pulse height resolution), and explain why this is indicative of system performance.

10. Describe qualitatively the operation of a multichannel pulse height analyzer used for obtaining gamma photon pulse height spectra.

11. Explain the operation of three types of data recording devices.

12. Describe the purpose and function of scalers. To be acceptable, two-state (flip-flop) circuitry must be described and practical applications identified.

13. Describe the properties of ratemeters, including explanation of time constants and their relationship to the rate of change of counting rates.

14. Describe the function and purpose of strip chart recorders. To be acceptable, the description must include the importance of the interrelation of ratemeter range and time constant, chart speed, and the rate of change of any physiologic process being recorded.

V. LIQUID SCINTILLATION COUNTERS

A. The student should be able to:

1. Describe liquid scintillation counting. The description should include functions of solvent, scintillator, fluor converter, and a simple description of the means of light collection from the liquid scintillator.

2. Describe a simplified coincident circuit and explain its function.

V. LIQUID SCINTILLATION COUNTERS (continued)

3. Describe the rationale for the quenching correction and how to carry out the calculation.

VI. COUNTING EFFICIENCY

A. The student should be able to.

1. Define the term "counting efficiency." The definition should include geometrical efficiency and absolute detector efficiency.

2. Describe the factors influencing counting efficiency. The factors of geometry, absorption, and scatter should be described in relation to overall counting efficiency.

3. Define intrinsic crystal efficiency in terms of crystal dimensions (size) and gamma (or X-ray) energy and in terms of total efficiency, peak efficiency, and peak-to-total ratio.

4. Describe the method of determining counting efficiency by use of a standard source with a known disintegration rate.

5. Calculate the absolute disintegration rate of a given radioactive source (and activity in curie units) from an observed count rate when provided with the efficiency of a counting system for that given radionuclide.

6. List the factors of importance when substituting a long-lived radionuclide as a comparison standard for a short-lived radionuclide for which a standard source cannot be maintained. The list must include type of decay, photon energy, and abundance.

VII. THEORY OF STATISTICS OF COUNTING

A. The student should be able to:

1. Define the term "probability" and identify the meaning of the limits of probability p = 1 and p = 0.

2. Differentiate between examples of systematic errors and random errors.

3. Differentiate between the terms "precision" and "accuracy."

4. Identify and label the axes on a graph of a probability distribution.

VII. THEORY OF STATISTICS OF COUNTING (continued)

5. Write the formulas for the mean and standard deviation of a Gaussian or normal distribution and describe the variance in terms of the standard deviation.

6. Write the formulas for the mean and standard deviation of a Poisson distribution, and explain the terms.

7. Differentiate between the Gaussian and Poisson distributions by differences in their distribution of continuous and discrete variables.

8. State the fraction of the Poisson distribution which lies between ± 1 standard deviation from the mean, ± 2 standard deviations from the mean, ± 3 standard deviations from the mean.

9. Identify the formula for the calculations of Chi-square and explain each term.

10. Describe the use of the Chi-square test for comparing an unknown distribution with a known distribution such as the Poisson distribution.

VIII. APPLICATION OF STATISTICS TO COUNTING DATA

A. The student should be able to:

1. Describe the relationship of the Poisson distribution to the statistics of radioactivity counting.

2. State the probability that the true value of a given radioactive count lies between ±1, ±2, and ±3 standard deviations from the mean.

3. Describe the effect on the fractional standard deviation of increasing the total counts.

4. Write the formula for the standard deviation of the difference between two radioactive counts.

5. Given two count rates in proportion to each other describe the effect on the standard deviation.

6. Write the formula for the calculation of the standard deviation of a count range, identifying all terms in the formula.

VIII. APPLICATION OF STATISTICS TO COUNTING DATA (continued)

7. Identify the formula for the calculation of the standard deviation of a ratemeter reading and all terms used in the formula.

8. Describe the effect on the standard deviation of a ratemeter reading of increasing and decreasing the ratemeter time constant.

9. Describe the use of the Chi-square test in testing counter performance.

10. Describe the use of a quality control chart for the evaluation of an instrument system which includes all sources of statistical variation.

ANATOMY, PHYSIOLOGY, AND PATHOLOGY II

Hours required

Class, 3; Laboratory, 1

Course Description

ANATOMY, PHYSIOLOGY, AND PATHOLOGY II is a continuation of ANATOMY, PHYSIOLOGY, AND PATHOLOGY I.

Major Divisions	Semester Class Hours	Semester Lab Hours
I. Circulatory System	12	6
II. Respiratory System	9	5
III. Urinary Tract	10	0
IV. Digestive System	9	4
V. Miscellaneous	3	0
1. Reticuloendothelial System		
2. Spleen		
3. Thymus		
VI. Introduction to Immunology	2	0
Total	45	15

I. Circulatory System

A. Units of Instruction

1. Brief survey of embryologic development of the cardiovascular and lymphatic systems

2. Blood constituents
   - a. Organs forming blood constituents
   - b. The sites and steps in the formation of the blood constituents (e.g. erythrocytes, leukocytes, thrombocytes)
   - c. Structure, composition, life cycle and functions of erythrocytes and thrombocytes
   - d. Classification, structure, composition, life cycle and functions of leucocytes
   - e. Composition and functions of plasma and its constituents
   - f. Introduction to factors involved in
     - i. Blood typing
     - ii. Hemostasis

3. Introduction to body defense mechanisms

4. Heart
   - a. Location, structure, and functions of the heart and its constituent parts (e.g. layers of the heart "wall", cardiac chambers, cardiac valves, coronary arteries)
   - b. Cardio-pulmonary circulatory system
     - i. Vascular structures composing the cardiopulmonary system and the direction of blood flow through the system
   - c. Nerve control and conduction system of the heart
   - d. Cardiac cycle, cardiac output, blood pressure

5. Vasculature
   - a. Direction of flow and major vessels involved in the transport of blood from the heart to any region of the body and back to the heart
     - i. Location, structure, and function of the major arteries and veins, including the systemic pulmonary and portal circulatory systems
     - ii. Structure and function of a typical artery, arteriole, capillary, venule and vein
   - b. Systemic factors involving the regulation of blood pressure and blood volume

6. Introduction to pathologic conditions affecting the circulatory system
   - a. Blood constituents
     - i. (e.g. myeloid metaplasia, leukemia, polycythemia vera)
   - b. Cardiac
     - i. (e.g. pericarditis, myocardial infarction, mitral stenosis, coronary artery occlusion, interventricular spetal defect)
   - c. Vasculature
     - i. (e.g. coarctation of the aorta, atherosclerosis, aneurysms, arteriovenous malformations, pulmonary embolization, thrombophlebitis)

7. Introductory survey of nuclear medicine hematologic and cardiovascular procedures (e.g. plasma volume and red cell mass studies, red cell survival half time and organ sequestration study, radionuclide cardiovascular angiogram, cardiac blood pool imaging)

8. Lymphatic System
   - a. Location, structures comprising the lymphatic system (e.g. lymphatic vessels, lymph nodes)
   - b. Function of the lymphatic system
   - c. Introduction to the pathologic conditions affecting the lymphatic system (e.g. lymphoma, leukemia)
   - d. Introduction to nuclear medicine studies related to the lymphatic system (e.g. radionuclide lymphangiogram, gallium-67 total body scan study)

B. Laboratory Projects

1. Blood Constituents
   - a. Microscopic examination of a stained blood smear
     - i. Identify and label a diagram of the constituents of the blood shown in the blood smear

2. Gross Anatomy
    a. Heart
        i. Demonstration of the components of the heart by models, prepared specimens
            (a) Label appropriate diagrams
        ii. Dissection of an animal heart with identification of its components by instructor and/or students
        iii. Demonstration of blood "flow" through the heart and lungs from images produced by radionuclide angiocardiographic studies and radiographic contrast angiocardiography
    b. Vasculature
        i. Demonstration of the major vessels comprising the vascular system by models, prepared specimens
        ii. Demonstration of blood "flow" through the body by radionuclide angiographic studies and selected radiographic contrast angiographic studies
3. Histology
    a. Examine prepared histologic sections of heart muscle, aorta, inferior vena cava, peripheral arteries and veins
4. Physiology
    a. Demonstration of blood pressure and pulse rate
        i. Demonstrate the use of the sphygmomanometer and stethoscope in determining blood pressure
    b. Cardiac sounds
        i. Listen to a recording of heart sounds
        ii. Use the stethoscope to listen to heart sounds in another student
    c. Demonstration of performance of a hematocrit, the preparation of a blood smear, and performing a differential count

II. Respiratory System

A. Units of Instruction
1. General
    a. Major structures of the respiratory system
    b. General functions of the respiratory system
    c. Brief survey of the embryologic development of the respiratory system
2. Nose
    a. Location, structure, and function of the nose and its constituent parts
3. Paranasal Sinuses
    a. Location, structure, and functions of the paranasal sinuses
4. Pharynx
    a. Location, structures comprising the pharynx and their functions
5. Larynx
    a. Location, structure, and functions of the larynx and its constituent parts
6. Trachea
    a. Location, structures, and functions of the trachea
7. Bronchi
    a. Location, structure, and functions of the bronchi and their constituent parts
8. Major structures composing the thoracic cavity (e.g. the subdivisions of mediastinum, pleural space and the pleura
9. Diaphragm
    a. Location, structure, and functions of the hemidiaphragm
10. Lungs
    a. Structure of the lungs
        i. Lobes, vasculature
        ii. Pulmonary alveoli and capillary network
    b. Function of the constituent parts of the lungs
11. Respiration
    a. Cellular respiration
    b. Pulmonary respiration
        i. Mechanics of respiration
        ii. Volume and pressure changes with respiration
        iii. Control of respiration by CNS. Arterial PO_2, PCO_2 and pH
        iv. Diffusion of gases, transport of gases in blood
        v. Pulmonary acid-base balance
12. Introduction to pathologic conditions affecting the lungs (e.g. neoplasms, chronic obstructive pulmonary disease, pulmonary embolization)
13. Introduction to nuclear medicine studies with the anatomic, physiologic, and pathologic correlation

B. Laboratory Projects
1. Gross Anatomy
    a. Demonstration by models and prepared specimens of the respiratory system
        i. Label appropriate diagram
    b. Dissection of a large animal's lung
    c. Demonstration of the bronchial and vascular pulmonary "tree" by radiographic studies (contrast bronchograms and contrast pulmonary arteriograms)

2. Histology
    a. Examination of prepared slides of the sections from the lungs
        i. Label appropriate diagrams
3. Physiology
    a. Demonstration of respiratory movements by model and/or movies including the thoracic cavity, diaphragm, etc.
    b. Demonstration of instrumentation used in determining vital capacity, tidal air volume, etc. (spirometer)
    c. Ausculation of the lungs
        i. Demonstration and practice on another student of the use of stethoscope in listening to respiratory sounds
    d. Demonstration of radionuclide pulmonary perfusion, ventilation, and inhalation studies and their relationship to pulmonary anatomy and physiology

III. Urinary Tract
  A. Units of Instruction
    1. General
        a. Major constituents of the urinary tract
        b. Primary functions of these major constituents
        c. Brief survey of the embryologic development of the urinary tract
    2. Kidneys
        a. Location and structure of the kidneys and their constituent parts
            i. Gross anatomy (e.g. medulla, cortex, calyces, vasculature)
            ii. Microscopic anatomy (e.g. glomerulus, the nephron and its components)
        b. Function of the renal components in the production of urine
            i. Physiologic factors involved in glomerular filtration, tubular reabsorption, and tubular secretion
            ii. Physiologic means for regulating urine content and volume (e.g. aldosterone, corticosteroids, antidiuretic hormone, counter-current concept)
    3. Ureters
        a. Location, structure, and function of the ureters
    4. Bladder
        a. Location, structure, and function of the bladder
    5. Urethra
        a. Location, structure, and function of the male and female urethra
    6. Introduction to pathologic conditions affecting the urinary tract (e.g. glomerulonephritis, pyelonephritis, unilateral renal artery stenosis, polycystic disease, ureteral obstruction secondary to calculus, or tumor, cystitis, urethritis, and neoplasms of the kidney, ureter or bladder)
    7. Introduction to nuclear medicine procedures relating to the urinary tract (e.g. radionuclide renal angiogram, renal imaging, renogram, measurement of effective renal plasma flow and glomerular filtration rate)

IV. Digestive System
  A. Units of Instruction
    1. General
        a. The major divisions of the gastrointestinal tract (e.g. pharynx, esophagus, stomach)
        b. Layers of the wall of the digestive tract and their function
        c. Brief survey of the embryologic development of the digestive system.
    2. Mouth
        a. Location, structure , and functions of the mouth and its constituent parts
    3. Salivary Glands
        a. Location, structure, and function of the salivary glands
    4. Pharynx
        a. Location, structure, and function of the pharynx and its subdivisions
    5. Esophagus
        a. Location, structure, and function of the esophagus
    6. Stomach
        a. Location and structure of the stomach and its constituent parts
        b. Function of the stomach (e.g. secretions, motility, digestive processes)
    7. Small Intestine
        a. Location and structure of the small intestine and its constituent parts (e.g. duodenum, jejunum and ileum; intestinal villi)
        b. Function of the small intestine and its constituent parts (e.g. secretions, motility, digestive processes and absorption)
    8. Large Intestine
        a. Location and structure of the large intestine and its constituent parts (e.g. cecum, appendix, ascending, transverse, descending and sigmoid colon)
        b. Function of the large intestine and its constituent parts (e.g. secretions, motility, absorption

9. Rectum
    a. Location, structure and function
10. Liver
    a. Location and structure of the liver, e.g. parenchymal cells, Kupffer cells, sinusoids
    b. Function of the liver and its constituent parts, e.g. digestive enzymes, hematopoiesis and coagulation, phagocytosis, detoxification, and metabolism
11. Gall Bladder
    a. Location and structure of gall bladder and constituent parts
    b. Function of gall bladder
12. Pancreas
    a. Location and structure of pancreas and constituent parts as an exocrine and endocrine gland
    b. Function of pancreas as an exocrine gland
        i. The enzymes produced by the pancreas and their function
13. Nervous, circulatory, and lymphatic systems in the digestive tract
    a. Review of structure and function of these systems in the digestive tract
14. Metabolism
    a. Carbohydrates, fats, proteins, and vitamins in metabolism
        i. Survey of these nutrients as to their basic constituents and their importance in body metabolism
            (a) E.g. ingested proteins are "broken down" to amino acids in the digestive tract enzymes absorbed and then serve as "building blocks" for protein which is the basic constituent of protoplasm.
    b. Energy metabolism
        i. Chemical energy
        ii. Basal metabolism rate
        iii. Regulation of body temperature
15. Introduction to pathologic conditions affecting the digestive tract
16. Introduction to nuclear medicine procedures which relate to the digestive tract (e.g. radionuclide salivary gland imaging, liver imaging, pancreas imaging, protein loss enteropathy study)

B. Laboratory Projects
    1. Gross Anatomy
        a. Demonstration of the constituents of the digestive tract from models, prepared specimens and radiographic contrast esophageal and gastrointestinal studies
        b. Dissection of the digestive tract of an animal with organ identification
            i. Label appropriate diagrams
    2. Histology
        a. Examine prepared tissue slides of various digestive organs
            i. Label appropriate diagrams
    3. Physiology
        a. Experiment involving the effect of saliva on starch
        b. Outline of the digestive enzymes, nutrients they affect and the resultant products of enzymatic activity

V. Miscellaneous

(1) Reticuloendothelial System

A. Units of Instruction

1. Brief survey of the embryologic development of the RE system
2. Location and structures comprising the reticuloendothelial system (e.g. spleen, bone marrow, hepatic Kupffer cells)
3. Functions of the reticuloendothelial system
4. Introduction to pathologic conditions affecting the RE system
    a. Reticuloendotheliosis (e.g. Gaucher's disease)
5. Introduction to nuclear medicine procedures relating to the RE system (e.g. bone marrow imaging with radionuclide labeled colloids)

(2) Spleen

A. Units of Instruction

1. Brief survey of the embryological development of the spleen
2. Location and structures comprising the spleen
3. Functions of the constituent parts of the spleen
4. Introduction to pathologic conditions affecting the spleen (e.g. splenic infarction, laceration, neoplastic invasion)
5. Introduction to nuclear medicine procedures relating to the spleen (e.g. radionuclide splenic imaging)

(3) Thymus

A. Units of Instruction

1. Embryology, location, structure, and function

VI. Introduction to Immunology

A. Units of Instruction

1. Introduction to immune response
2. Antibody-antigen reactions
3. Antibody structure and formation
4. Overview of antibodies

PERFORMANCE OBJECTIVES FOR ANATOMY, PHYSIOLOGY, AND PATHOLOGY II

I. CIRCULATORY SYSTEM

A. The student should be able to:

1. State where the first site of blood development in the chick embryo is.
2. Identify the embryologic germ layer from which blood and heart develops.
3. Identify 3 sites of blood formation.
4. Describe the principal functions of the blood. To be acceptable, the description must include transportation of minerals to cells (nutrients, water, oxygen, hormones to cells; urea, carbon dioxide, etc. to organs of excretion), transportation of materials from cells (urea, carbon dioxide, hormones, antibodies, enzymes; regulation of heat within the body).
5. Identify the fluid elements of the blood. To be acceptable, this must include: water, proteins, electrolytes, gases, lipids, sugars, amino acids, hormones, antibodies, enzymes, etc.
6. Define and give the characteristics and developmental sequence of the blood's major formed elements. To be acceptable, the description must include:
    a. Erythrocytes
    b. Leukocytes
    c. Thrombocytes.
7. State the primary function of erythrocytes and leukocytes.
8. Describe the nature and basic function of hemoglobin.
9. Describe the major functions of the blood plasma.
10. Describe the basic structure of the cardiovascular system.
11. Describe the basic functions of the vascular system.
12. Describe the basic anatomic features of the heart as related to function. To be acceptable, the description must include: the role of the valvular structures and the heart's own circulation system; the role of the pericardium in cardiac function.

I. CIRCULATORY SYSTEM (continued)

13. Describe the manner in which the myocardium is stimulated to contract.

14. Describe the flow of blood through the heart in the correct chronological order.

15. Name the three layers of the arterial wall and describe the type of tissue comprising each.

16. Explain structure and function of arteries, arterioles, capillaries, venules, and veins.

17. Describe the major disease categories of the heart and great vessels.

18. Describe the clinical characteristics of shunting, aneurysm, valvular stenosis, and insufficiency.

19. Describe the characteristics and properties of the circulatory flow of blood as applicable to any part of the body. To be acceptable, the description must include: flow through the heart, flow through both blood-vascular subdivisions, arterial blood flow, capillary flow, venous flow, and blood-tissue nutrient-waste exchange.

20. Describe the major blood pools of the body including at least the following categories: 25% in heart, lung vessels, and large blood vessels; 25% in liver; 25% in striated muscles; and 25% in the remaining organs. The description should include the fraction of blood that is solid elements in the large vessels, whole body, and in the major organ systems. The description to be acceptable should include the muscle, brain, liver, spleen, intestines, and kidney.

21. Describe the difference between leukemia and polycythemia vera.

22. Describe the difference between chronic and acute leukemia.

23. Describe the difference between pericarditis, and endocarditis.

24. Describe myocardial enfarct.

25. Define the term "aneurysm."

26. Define the term "thrombosis."

I. CIRCULATORY SYSTEM (continued)

27. Identify the isotope most commonly used for myocardial scanning.

28. Describe the difference between a cardiac scan, a myocardial scan, and a radioisotope angiocardiogram.

29. Describe the relationship between cardiac diameter on X-ray, and on cardiac scan.

30. Identify the condition commonly investigated by cardiac scanning.

31. Identify the disease commonly investigated by myocardial scanning.

32. Describe the radioisotope cardiac output study.

33. Identify two radioisotopes commonly used in performing blood volume determinations.

34. Identify the isotope commonly used to tag red blood cells in performing red cell survival studies.

35. Specify the average red cell survival time.

36. Describe the anatomical difference between lymphatic and blood vessels.

37. Describe the basic function of the lymphatic system.

38. Identify a disease of the lymphatic system commonly investigated with nuclear medicine procedures and identify that procedure.

39. Identify two diseases which may be investigated on the gallium scan.

II. RESPIRATORY SYSTEM

A. The student should be able to:

1. Name the structures and their functions included in the respiratory system. To be acceptable, these must include: the nasal cavity, paranasal sinuses, larynx, trachea, bronchi, bronchioles, and lungs.

2. Describe where the lungs begin development in the human embryo.

II. RESPIRATORY SYSTEM (continued)

3. Identify two embryological germ layers from which the respiratory system evolves.

4. Discuss the meaning of the terms lung perfusion and lung ventilation.

5. Name and state the number of and inside diameter of the smallest blood vessels in the lungs.

6. Describe the pathway which oxygen follows from the nose to a cell.

7. Define the various depths of respiration.

8. Describe the location, anatomy, and function of the nasal cavity.

9. Describe the location, anatomy, and function of the paranasal sinuses.

10. Describe the location, anatomy, and function of the pharynx.

11. Describe the location, anatomy, and function of the larynx.

12. Describe the anatomy of the trachea including shape, size, location, and contiguous structures, and explain its function.

13. Describe the four layers of the trachea.

14. Describe the anatomy of the major bronchi including shape, location, histology, and branching systems, and explain their functions.

15. Describe the divisional characteristics of the bronchi in the lungs ultimately resulting in bronchioles.

16. Describe the branching system of the smaller bronchi, bronchioles, and aveoli.

17. Describe the anatomy of the diaphragm, and explain its function.

18. Identify the lobes and major segments of the lungs.

19. Identify the controlling factors of respiration including arterial PO_2, PCO_2, and pH.

II. RESPIRATORY SYSTEM (continued)

20. Describe the altered histology and anatomy found in the following pathological conditions of the respiratory system: pulmonary embolism, emphysema, asthma, pneumonia, neoplasm, pleural effusion, tuberculosis, and pneumothorax.

21. Describe in detail the altered physiology of the respiratory system as found in the pathological conditions listed above.

22. Name and describe at least 10 common clinical manifestations encountered in the above listed pathological conditions.

23. State and explain special care and the associated procedures that may be required for patients with the pathological conditions listed above in objective#20 including at least oxygen therapy and oxygenation of the patient, masking and proper isolation procedures, maintenance of open airway, and proper positioning of the patient for ventilation.

24. State for which of the above listed pathological conditions listed in objective#20 masking and all associated isolation procedures are required for the protection of technicians and other personnel against the infection.

25. Describe the difference between perfusion, ventilation, and inhalation studies.

26. Describe the term "capillary blockade."

27. Describe how X-rays of the chest are correlated with the nuclear medicine perfusion and ventilation studies.

28. Discuss the V/Q ratio.

29. Identify the pulmonary disease most commonly investigated by nuclear medicine procedures.

III. URINARY TRACT

A. The student should be able to:

1. Name the major components of the genitourinary system including the kidneys, ureters, urinary bladder, and urethra.

III. URINARY TRACT (continued)

2. State the major functions of the urinary system including at least excretion of toxic substances and waste products of metabolism, maintenance of proper water balance in the body, maintenance of proper concentration of salts and other substances in the blood, and maintenance of proper acid-base equilibrium in body fluids.

3. Identify the embryologic germ layer from which the urinary tract develops.

4. Embryologically, what other system's development closely follows the development of the urinary tract.

5. State the anatomical features of the kidneys including location, size, weight, and shape.

6. Describe the hilum of the kidney.

7. Name the structures which connect to each kidney at the hilum including renal artery, renal vein, lymph vessels, nerves, and ureter.

8. Name the two general regions of the kidney.

9. Name the structural and functional units of the kidneys.

10. State the number of these units in each kidney.

11. Name the structures which comprise the nephron including at least the glomerulus, Bowman's capsule, proximal convulated tubule, loop of Henle, distal convoluted tabule, collecting tube, and papillary duct.

12. Describe the glomerulus.

13. Describe the function of the glomerulus.

14. Describe Bowman's capsule including at least its shape, being structurally part of the tubule, and enclosing the glomerulus.

15. Describe the function of Bowman's capsule.

16. Describe the proximal convoluted tubule, loop of Henle, and distal convoluted tubule with emphasis on the course they follow and its association with its capillary plexus.

17. Describe the function of the papillary ducts and minor calyx.

III. URINARY TRACT (continued)

18. Describe the anatomy of the ureters, bladder, and urethra, and explain their functions.

19. Describe the altered histology and anatomy found in the following pathological conditions of the genitourinary system: renal neoplasm, cysts, infarction, trauma, ureteral obstruction, inflammatory processes, and hypertension in so far as the role played by the kidneys.

20. Describe the altered physiology of the genitourinary system as found in each of the pathological conditions listed in objective #19.

21. Describe three nuclear medicine procedures used in the evaluation of urinary tract disease.

22. Explain what is meant by a functional study of the kidneys.

23. Describe the difference between the IVP, the renal scan, and the renogram.

24. Describe the difference between renal arteriograms performed with contrast media; and radioisotopes.

25. Define the term "ectopic kidney."

26. Describe the condition of azotemia.

27. State what common laboratory value is noted when performing radioisotopic renal studies.

IV. DIGESTIVE SYSTEM

A. The student should be able to:

1. Describe the general anatomy, histology, and physiology of the digestive system. To be acceptable, the description must include the following: mouth, salivary glands, esophagus, pharynx, stomach, duodenum, ileum, colon, rectum, anus, pancreas, and liver.

2. Describe the normal functions of each of the above.

3. Describe three layers of the digestive tract.

4. Describe the location, structure, and function of the mouth.

5. Describe the location, structure, and function of the salivary glands.

IV. DIGESTIVE TRACT (continued)

6. Identify four anatomical features and list three major functions of the stomach.

7. Identify three segments of the small intestine, and describe their basic function.

8. Identify five segments of the large intestine, and describe their basic function.

9. Describe the structure and function of the rectum.

10. List six functions of the liver.

11. Contrast polygonal and Kupffer cells in terms of structure and function.

12. Describe the location, structure, and function of the gall bladder.

13. Describe the exocrine and endocrine portion of the pancreas gland.

14. Describe the digestion process of proteins, carbohydrates, and fats including their breakdown, and reconstitution in the cell.

15. Relate the definition of calorie to chemical energy.

16. Describe the mechanism for the control of basal metabolism.

17. Describe the mechanism for the regulation of body temperature.

18. Discuss several pathologic conditions affecting the digestive tract which may be detected with nuclear medicine procedures.

19. Describe Sjögren's syndrome and identify the nuclear medicine procedure used in its evaluation.

20. Describe five hepatic diseases which may be studied using nuclear medicine procedures.

21. Explain how the Rose bengal study may be used to distinguish between intra and extra hepatic obstruction.

22. Explain the meaning of pseudocyst of the pancreas.

23. Identify three diseases of the pancreas which may result in a positive pancreas scan.

IV. DIGESTIVE TRACT (continued)

24. Explain why morphine may be administered prior to a pancreas scan.
25. Identify the isotope commonly used when performing an enteropathy study.

V. MISCELLANEOUS

A. The student should be able to:

1. Describe the function of the recticuloendothelial system in the embryo.

2. Identify three areas in the body where recticuloendothelial tissue may be found.

3. Describe the functions performed by the recticuloendothelial system.

4. Describe the phenomenon of compensatory hyperactivity of the recticuloendothelial system.

5. Explain how the process of phagocytosis is essential to the nuclear medical evaluation of reticuloendothelial disease.

6. Identify the four anatomical structures that the spleen touches in its normal anatomic placement.

7. Describe two types of splenic tissue. To be acceptable, definition must include red pulp and white pulp.

8. Identify two types of blood cells manufactured in the adult by the spleen. To be acceptable, lymphocytes and monocytes must be identified.

9. Describe the spleen's role in the production of antibodies.

10. Define the term "splenomegaly."

11. List common causes of splenomegaly. To be acceptable, the list must contain: portal hypertension, subacute infective endocarditis, leukemia, polycythemia vera.

12. Define the term "accessory spleen." To be acceptable, the definition must state that this condition is found in 10% of the population.

13. List the common locations of accessory spleens.

V. MISCELLANEOUS (continued)

14. Explain why radioactive colloids are used to perform nuclear medicine examinations of the spleen.

15. Explain how phagocytosis in the spleen may be used to perform a nuclear medicine examination of the spleen.

16. Describe the embryological development of the thymus gland.

17. Explain the location, structure, and function of the thymus gland.
18. Define involution of the thymus gland.

VI. INTRODUCTION TO IMMUNOLOGY

A. The student should be able to:

1. Describe the difference between lysins, agglutins, and antitoxins.

2. Define the terms "antitoxin," "toxin," and "toxoid."

3. Define the terms "antibody" and "antigen" and discuss their functions.

4. Discuss how antibodies are probably formed.

5. Discuss the difference between active and passive immunity.

6. Discuss the function of complement.

7. Define the term "vaccine."

8. Define the term "anaphylaxis."

CHEMISTRY FOR THE HEALTH SCIENCES

Hours Required

Class, 3; Laboratory, 3

Course Description: CHEMISTRY FOR THE HEALTH SCIENCES provides the student with those concepts of inorganic chemistry, organic chemistry, and biochemistry most applicable to nuclear medicine technology. It prepares the student for the radiochemistry and radiopharmacy course which follows. Laboratory projects stress the proper use of the types of apparatus used in the preparation of radiopharmaceuticals including pH meters, centrifuges, balances, filter flasks and pipets.

Major Divisions		Semester Class Hours	Semester Lab Hours
I.	Measurement	5	9
II.	Concepts of Matter, Energy, and the Atom	3	0
III.	Fundamentals of Chemistry	5	6
IV.	Oxidation-Reduction	3	0
V.	Liquid Mixtures	5	12
VI.	Chromatography	3	3
VII.	Acids and Bases	4	6
VIII.	Salts	2	3
IX.	Ionization	3	0
X.	An Introduction to Organic Chemistry	6	3
XI.	An Introduction to Biochemistry	6	3
	Total	45	45

I. Measurement

A. Units of Instruction

1. The metric system
2. Gravimetric methods
3. Gravimetric analysis
4. Volumetric methods
5. Density and specific gravity
6. Electrical measurements and interrelationships
7. Graphs-construction and analysis

B. Laboratory Projects

1. Weigh a coin on a given scale several times and on different balances , and explain the results in terms of accuracy and precision.
2. Pipet prescribed volumes of water using most appropriate pipet for each amount.
3. Given various pipets, graduated cylinders, and balances, determine the density of water by plotting the mass vs volume for a wide range of volumes.

II. Concepts of Matter, Energy, and the Atom

A. Units of Instruction

1. Matter
2. Energy
3. Atomic structure

Fundamentals of Chemistry

A. Units of Instruction

1. The nature of the chemical bond
2. Formulas and nomenclature
3. The mole concept and stoichiometric equiations

B. Laboratory Projects

1. Have two problem-solving sessions to calculate weight of reaction products for several chemical equations.

IV. Oxidation-Reduction

A. Units of Instruction

1. Oxidation definition
2. Reduction definition
3. Oxidizing agents and reducing agents
4. Medical importance of oxidation-reduction

V. Liquid Mixtures

A. Units of Instruction

1. Solutions
   - a. Types of solvents
   - b. Factors effecting solubility of solid solute
   - c. Concentration of solutions
   - d. Special properties of solutions
   - e. Isotonic, hypotonic, and hypertonic solutions
2. Suspensions
3. Colloids
   - a. Size
   - b. Surface area
   - c. Absorption
   - d. Electrical charge
   - e. Tyndal effect
   - f. Brownian movement
   - g. Dialysis
4. Emulsion

B. Laboratory Projects

1. Have a problem-solving session for computing solution concentration.
2. Given a sugar solution and a membrane stretched over the end of a thistle tube, demonstrate osmotic pressure as a function of sugar concentration.
3. Given a variety of unknown solutions and a colloidal suspension, use the Tyndal effect to distinguish between solutions and colloids.
4. Prepare a colloidal solution and use a centrifuge to separate the colloid particle sizes.

VI. Chromatography

- A. Units of Instruction
  - 1. Principles of operation
    - a. Adsorption
    - b. Partition
    - c. Ion-exchange
  - 2. Paper chromatography
  - 3. Column chromatography
  - 4. Thin layer chromatography
  - 5. Electrophoresis
- B. Laboratory Projects
  - 1. Given filter paper, green leaves, and acetone, separate various components from leaf by paper chromatography.

VII. Acids and Bases

- A. Units of Instruction
  - 1. Acid-Base titrations
  - 2. The concept of pH
  - 3. Buffers and pH
- B. Laboratory Projects
  - 1. Given a known concentration of an acid and an unknown concentration of given base, titrate to find the normality of the base.
  - 2. Given a pH meter, buffer solution of known pH, and narrow range pH test paper the student must calibrate the instrument and measure the pH of an unknown buffer solution.

VIII. Salts

- A. Units of Instruction
  - 1. Solubility of salts
  - 2. Types of salts
  - 3. Uses of salts
- B. Laboratory projects
  - 1. Experimentally determine the solubility of NaO in H_2O at 100°C and at room temperature.

IX. Ionization

- A. Units of Instruction
  - 1. Conductivity of solutions
  - 2. Effect of electrolytes on boiling points and freezing points
  - 3. Theory of ionization
  - 4. Conductivity of solutions of electrolytes
  - 5. Strong and weak electrolytes
  - 6. Other evidence of ionization
  - 7. Importance of ions in body chemistry

X. An Introduction to Organic Chemistry

- A. Units of Instruction
  - 1. Organic structure of hydrocarbons and their radicals
  - 2. Structured alkanes
  - 3. IUPAC classification system
  - 4. Important organic reactions
  - 5. Aromatic compounds and reactions
  - 6. Heterocyclic compounds
- B. Laboratory Projects
  - 1. Have problem solving session on naming organic compounds from structural formula and vice versa.

XI. An Introduction to Biochemistry

- A. Units of Instruction
  - 1. Carbohydrates
  - 2. Fats
  - 3. Proteins
  - 4. Enzymes
  - 5. Metabolism
  - 6. Body fluids
  - 7. Vitamins
  - 8. Hormones
- B. Laboratory Projects
  - 1. Have review session

Texts and References

Cherim. Chemistry for Laboratory Technicians

Sackheim and Schultz. Chemistry for the Health Sciences

Schaum. College Chemistry

Snyder. Chemistry-Structure and Reactions

PERFORMANCE OBJECTIVES FOR CHEMISTRY IN THE HEALTH SCIENCES

I. MEASUREMENT

A. The student should be able to:

1. Convert a U.S. length measurement to the metric system. To be acceptable the demonstration must include the ability to use correctly the definitions and abbreviations for: kilometer, meter, centimeter, millimeter, micron, and millimicron (nanometer).

2. Convert a U.S. weight measurement to the metric system. To be acceptable, the demonstration must include the ability to use correctly the abbreviations and definitions for kilogram, gram, milligram, and microgram.

3. Convert a U.S. volume measurement to the metric system. To be acceptable the demonstration must include the ability to use correctly the abbreviations and definitions for liter, milliliter, microliter (lambda), and nanoliter.

4. Convert a temperature in Fahrenheit units to Centigrade and Kelvin units.

5. Define the term "density" and give its formula.

6. Define the term "specific gravity" and give its formula.

7. Describe the relationship between specific gravity and density.

8. Describe a procedure for identifying those liquids with a density which is different from the density of water. To be acceptable, the student must include examples of liquids which have both a greater and lower density.

9. Specify the effect of an increase in temperature on the change in the density of water.

10. Calculate an object's density, given its volume and weight.

11. From the calculated density value, re-express as specific gravity the calculated density value.

12. Given an unknwon object and an analytical balance with a set of weights, determine the actual weight to the nearest milligram. To be acceptable, the procedure must include proper zeroing of the balance, correct use of the "rough weight" position of the balance release lever, correct interpretation

I. MEASUREMENT (continued)

of the actual weight values obtained, and proper care of the balance after the weighing is completed (including removal of weights from the beam, proper cleaning of the balance pan, and closing of the balance case.)

13. Identify the various types of calibrated laboratory glassware and their use. To be acceptable, the student shall identify volumetric flasks, burettes, pipets, graduated cylinders, and describe their use in the laboratory.

14. Demonstrate the techniques for proper use of the pipet, given a liquid and a particular pipet. To be acceptable, the demonstration must illustrate use of the following:
    a. To deliver pipets (TD)
    b. To contain pipets (TC)
    c. Blow-out pipets
    d. Serological or graduated pipets
    e. Volumetric pipets (TD)
    f. Automatic pipets
    g. Micro pipets and micro syringes
    h. Disposable 1 and 5 lambda pipets.

15. Define precision and accuracy in respect to multiple assays. To be acceptable, the student must show the method of calculating precision when given a set of numbers representing assay results, and relate the value to accuracy when given another number representing the true value.

16. Identify various types of general laboratory ware and describe their use. To be acceptable the student must show correct use of funnels (including use with filter paper for filtration), filter flasks, membrane filter systems (such as millipore systems), and separatory funnels.

II. CONCEPTS OF MATTER, ENERGY, AND THE ATOM

A. The student should be able to:

1. Define the basic units of matter. To be acceptable, the definitions must include those for an atom, molecule, and the subatomic particles such as protons, neutrons, and electrons.

2. Describe the basic structure of an atom. To be acceptable, the description must include the basic parts of the atom, and the simple subatomic particles associated with each part.

3. Describe the characteristics of an atom which determine its atomic number and atomic weight. To be acceptable, the student must show the role of the electron, proton, and neutron.

II. CONCEPTS OF MATTER, ENERGY, AND THE ATOM (continued)

4. Give the value of Avogadro's number and show its relation to a mole.

5. Define the terms "isotope," "isobar," "nuclide," and differentiate isobar and nuclide from isotope.

III. FUNDAMENTALS OF CHEMISTRY

A. The student should be able to:

1. Identify the common atomic symbols and give their basic meanings or derivations. To be acceptable, the atomic symbols must include the following:

   H, C, N, O, F, Li, Na, K, Ca, Mg, Cu, Fe, Ni, Al, Co, Cr, Ag, Au, P, S, Tc, I, Cl, Br, Mo, Sn, Sr, In, Xe, and Hg.

2. Explain the meaning of the symbol Tc^{99m}.

3. Calculate the molecular weight of a compound given the chemical formula and atomic weights of individual elements.

4. Describe how the chemical elements are assigned to the Periodic Table by gradation of various properties and atomic number. To be acceptable, the description must include a summary statement of similar chemical properties of a typical group or subgroup of elements due to electron configuration.

5. Describe properties for various element groups of the Periodic Table. To be acceptable, the student must show the valence number (or numbers), the valence sign (positive or negative), and the chemical properties (such as metal or nonmetal characteristics) of the various groups including the transition elements, actinides, and lanthanides.

6. Identify the valence of each element in a compound.

7. Specify the conditions for an atom to have a positive or negative valence. To be acceptable, the student must give a valid example of an atom which commonly has a positive valence and one which commonly has a negative valence.

8. Give an example of a simple chemical equation. To be acceptable, the student must balance the equation correctly.

9. Specify conditions that will cause a chemical reaction to occur, or which will affect its rate. To be acceptable, the must include a discussion of the effect of concentration of reactants, pH, temperature, and electron affinities.

IV. OXIDATION-REDUCTION

A. The student should be able to:

1. Describe the basic concepts of oxidation-reduction reactions. To be acceptable, the student must illustrate the potential valence changes by use of one of the following reactions:

   The reduction of ferric ion with ascorbate, the reduction of pertechnetate with iron/ascorbate or stannous ions.

V. LIQUID MIXTURES

A. The student should be able to:

1. Define and distinguish the properties of the states of matter: gas, liquid, and solid.

2. Define the terms "solution," "solvent," "solute," and "solubility."

3. State the effects of temperature, pressure, and the nature of the solvent on the solubility of a solute.

4. Describe and define various types of solutions and concentrations including:
   a. Saturated
   b. Percent
   c. Molarity
   d. Molality
   e. Normality..

5. Given a known weight of chemical dissolved in a solvent of a given volume, calculate the molarity or normality of the solution.

6. Describe the method for diluting solutions of known normality or molarity to desired lower values. To be acceptable, the student must describe how to prepare specified volumes of the diluted solutions.

7. Demonstrate the proper use of a centrifuge. To be acceptable, the demonstration must include the following procedural steps:
   a. The proper balancing of the centrifuge tubes.
   b. The setting of the time and speed to the desired values.
   c. The correct usage of the centrifuge braking system or the correct way to stop a centrifuge not equipped with a brake.
   d. The proper maintenance of the motor, including lubrication and inspection for worn brushes.

V. LIQUID MIXTURES (continued)

8. Given a microscope, an ocular hemocytometer, and/or stage micrometer, show the proper procedure to be used to measure colloid particle size. To be acceptable, the student shall:
    - a. Select the proper light filter.
    - b. Focus the light source properly on the reflecting mirror.
    - c. Adjust for the correct light intensity.
    - d. Select the lowest magnification which will permit the desired observation.
    - e. Use the traverse knobs to correctly scan the object in all directions.
    - f. Correctly clean the microscope and stage after use.

VI. CHROMATOGRAPHY

A. The student should be able to:

1. Identify four methods of chromatography. To be acceptable, response must include gas, liquid, gel, and paper chromatography.

2. Describe the basic differences between the chromatographic methods identified in objective #1.

3. Define the term "thin layer chromatography."

4. Describe basic features of chromatographic columns.

5. Describe the functions of the solvent and absorbent.

VII. ACIDS AND BASES

A. The student should be able to:

1. Differentiate between general properties of acids and bases. To be acceptable, the differentiation must include a differentiation of strong and weak acids and strong and weak bases.

2. Describe the relationship of hydrogen ion concentration to pH. To be acceptable, the student must give the definition of pH.

3. Describe the practical application of hydrogen ion concentration to pH. To be acceptable, the student must calculate pH from a given simple ionization constant of an acid.

4. Describe the general characteristics of buffer solutions. To be acceptable the student must explain the action of an acidic and an alkaline buffer on an increase or decrease in pH.

VII. ACIDS AND BASES (continued)

5. Describe the general principle of the pH meter and its use, given a pH meter, buffer solutions of known and unknown pH, and narrow range pH test paper. To be acceptable, the student must demonstrate the following steps in a procedural checklist and explain the reason for the steps:
   a. Proper electronic warm-up.
   b. Use of constant temperature of solutions being measured.
   c. The rinsing of electrodes before and after use.
   d. Use of standard buffers to calibrate the instrument.
   e. Use of narrow range pH test paper for rough comparison.
   f. Reading of values that are displayed by the instrument.
   g. Storing electrodes in distilled water after use.

VIII. SALTS

A. The student should be able to:

1. Define the term "salt." To be acceptable, definition must include compounds made up of positive and negative ions.

2. List three examples of salts.

3. Identify the salt in the following chemical reaction:

   $Ag^+ + (NO_3^-) + (Na^+) + Cl^- \_\_\_ AgCl + (Na^+) + (NO_3-)$

4. Identify a method of preparing salts.

5. From the following list, identify which are salts: HCl, NaCl, $BaSO_4$, H_2SO_4, H_2O, AgCl.

IX. IONIZATION

A. The student should be able to:

1. Describe ion.

2. Distinguish the difference between anions and cations.

3. Define the terms "solvent" and "solute."

4. Describe the process of ionization. To be acceptable, description must include the reaction between solute and solvent which results in ion formation.

5. Define the term "ionization constant."

X. AN INTRODUCTION TO ORGANIC CHEMISTRY

A. The student should be able to:

1. Describe what types of compounds are studied in organic chemistry.
2. Define the term "hydrocarbons."
3. Identify the following hydrocarbons:

   CH_4, C_2H_6, C_3H_8, C_4H_{10}

4. Write the chemical structure for methane, ethane, propane, and butane.
5. Describe the difference between saturated and unsaturated hydrocarbons.
6. Define the term "functional group."
7. Describe the difference between polymers and monomers.
8. Describe the difference between open chain and cyclic hydrocarbons.
9. Give an example of an aromatic hydrocarbon.
10. Identify a characteristic common to all alcohols.

XI. AN INTRODUCTION TO BIOCHEMISTRY

A. The student should be able to:

1. Define the science of biochemistry. To be acceptable, the definition must include the chemistry of the substances comprising living organisms, plants, and animals.
2. Identify a characteristic common to all proteins.
3. Identify five proteins.
4. Define the term "polypeptide."
5. Define the term "amino acid." To be acceptable, the definition must include product of protein breakdown.
6. Name three elements common to many carbohydrates.

XI. AN INTRODUCTION TO BIOCHEMISTRY (continued)

7. Identify the most important carbohydrates. To be acceptable, the list must include sugars and starches.

8. Identify 6 sugars.

9. Define the term "enzyme." To be acceptable, definition must include accelerator of chemical reactions.

10. Relate coenzyme to aopenzyme and enzyme.

MEDICAL TERMINOLOGY

Hours Required

Class, 2; Laboratory, 0

Course Description

MEDICAL TERMINOLOGY is designed to enable students to understand words as they appear throughout the curriculum.

The NMT will learn to communicate verbally or in written form with professional workers in the health fields, with medical secretaries, nurses, hospital administrators, and other hospital technologists.

Major Divisions		Semester Class Hours
I.	Orientation to Medical Terminology	3
II.	Terminology Related to Skin and Skin Disorders	3
III.	Terminology Related to Muscular and Skeletal Systems	3
IV.	Neurological and Psychiatric Terminology	3
V.	Cardiovascular Terminology	3
VI.	Blood and Blood-Forming Organ Terminology	3
VII.	Respiratory Terminology	3
VIII.	Digestive System Terminology	3
IX.	Urogenital and Gynecological Terminology	3
X.	Sense Organ Terminology	3
	Total	30

I. Orientation to Medical Terminology

A. Units of Instruction

1. Objectives
2. Elements of medical terms
3. Terms pertaining to body as a whole
    a. Anatomical divisions of abdomen
    b. Divisions of the back
    c. Position and direction
    d. Planes of the body

II. Terminology Related to Skin and Skin Disorders

A. Units of Instruction

1. Skin
2. Radiology
3. Nuclear medicine
4. Clinical laboratory
5. Abbreviations

III. Terminology Related to Muscular and Skeletal Systems

A. Units of Instruction

1. Bones
2. Joints, cartilages, and ligaments
3. Radiology
4. Nuclear medicine
5. Clinical laboratory
6. Abbreviations

IV. Neurological and Psychiatric Terminology

A. Units of Instruction

1. Nerves
2. Brain and spinal cord
3. Psychiatric disorders
4. Radiology
5. Nuclear medicine
6. Clinical laboratory
7. Abbreviations

V. Cardiovascular Terminology

A. Units of Instruction

1. Heart and coronary arteries
2. Arteries, capillaries, and veins
3. Radiology
4. Nuclear medicine
5. Clincal laboratory
5. Abbreviations

VI. Blood and Blood-Forming Organ Terminology

A. Units of Instruction

1. Blood
2. Lymphatic system
3. Spleen
4. Radiology
5. Nuclear medicine
6. Clinical laboratory
7. Abbreviations

VII. Respiratory Terminology

A. Units of Instruction

1. Nose
2. Sinuses
3. Larynx
4. Trachea
5. Lungs
6. Bronchi

   7. Radiology
   8. Nuclear medicine
   9. Clinical laboratory
   10. Abbreviations

VIII. Digestive Terminology

A. Units of Instruction

   1. Mouth
   2. Salivary glands
   3. Pharynx
   4. Esophagus
   5. Stomach
   6. Liver and intestines
   7. Radiology
   8. Nuclear medicine
   9. Clincal laboratory
   10. Abbreviations

IX. Urogenital and Gynecological Terminology

A. Units of Instruction

   1. Kidneys
   2. Bladder
   3. Male genital organs
   4. Female genital organs
   5. Radiology
   6. Nuclear medicine
   7. Clinical laboratory
   8. Abbreviations

X. Sense Organ Terminology

A. Units of Instruction

   1. Eye
   2. Ear
   3. Radiology
   4. Nuclear Medicine
   5. Clinical laboratory
   6. Abbreviations

Texts and References

Schmidt. Practical Nurses Medical Dictionary

Smith. Medical Terminology, A Programmed Text

Frenay. Understanding Medical Terminology

SEMESTER 3

SEMESTER 3

Nuclear Instrumentation II

Clinical Practicum I

Clinical Nuclear Medicine Technology I

Fundamentals of Radiochemistry & Radiopharmaceuticals

NUCLEAR INSTRUMENTATION II

Hours Required

Class, 3; Laboratory, 3

Course Description

NUCLEAR INSTRUMENTATION II is designed to further the student skills of operating, calibrating, and performing routine maintenance on scanners, gamma cameras, well counters, and liquid scintillation counters. In addition, the student is introduced to darkroom skills, as well as operation of video tape cameras and digital computers.

Major Divisions

		Semester	
		Class Hours	Lab Hours
I.	Types of Imaging Systems	6	9
II.	Photographic Film Processing	3	0
III.	Collimation	6	0
IV.	Parameters of Imaging Systems	6	12
V.	Resolution Determination in Imaging Systems	3	9
VI.	Instrumentation Quality Control	6	6
VII.	Recording Equipment for Dynamic Studies	3	3
VIII.	Computer Data Analysis and Display	9	6
	Total	45	45

I. Types of Imaging Systems (design and operation)

A. Units of Instruction

1. Rectilinear scanners
2. Stationary imaging devices
3. Solid-state imaging devices

B. Laboratory Projects

1. Given a manual for a rectilinear scanner, draw a block diagram and describe the functions of each block.
2. Given a manual for a gamma camera, draw a block diagram and describe the functions of each block.

II. Photographic Film Processing

A. Units of Instruction

1. Basic mechanisms of image production
2. Light transmission from subject to film
3. Film processing in practical use

B. Laboratory Projects

(Film development practice occurs in all subsequent experiments using a scanner.)

III. Collimation

A. Units of Instruction

1. Definition
2. Materials
3. Types of collimators
4. Collimator features
   a. Length
   b. Septal thickness
   c. Geometry
5. Collimator resolution and efficiency
6. Use of Collimators

IV. Parameters of Imaging Systems

A. Units of Instruction

1. System resolution and sensitivity
2. Information density
   a. Count rate
   b. Speed of scan
   c. Line spacing
3. Contrast enhancement
   a. Control settings
   b. Time constant of ratemeter
4. Dead time
5. Uniformity of response and zero suppression

B. Laboratory Projects

1. Given a scanner, a thyroid phantom filled with ^{99m}Tc and covered by two inches of water in a plastic tray, vary the setting of the P.H.A. window for optimum resolution.
2. Do the same experiment with a gamma camera.
3. Given a scanner with a phantom, vary the speed, and note what information densities give acceptable images. Also vary the time constant and contrast enhancement settings.
4. Given a gamma camera with two phantoms, vary the total counts for each phantom and note what information densities give acceptable images.

V. Resolution Determination in Imaging Systems

A. Units of Instruction

1. Point and line source
2. Modulation transfer function

B. Laboratory Projects

1. Given a scanner and two line sources, measure the resultion of the instrument by varying the line spacing.
2. Given a scanner, line sources, and several collimators, measure the resolution, relative sensitivity, and focus of each collimator.

3. Given a gamma camera, line sources, and several collimators, measure the resolution, sensitivity, and field of view of each collimator.

VI. Instrumentation of Quality Control

A. Units of Instruction

1. Determination of operating voltage and gain
2. Determining detector efficiency
3. Determining linearity
4. Effect of background on counting accuracy

B. Laboratory Projects

1. Given a scanner, perform quality control checks including standard source counting.
2. Given a gamma camera, perform quality control checks including linearity of response to flood sources and bar phantoms.

VII. Recording Equipment for Dynamic Studies

A. Units of Instruction

1. Automatic film sequencing (cine, 70 cm, etc.)
2. TV and video tape
3. Digital recording

B. Laboratory Projects

1. Given manuals of equipment which record dynamic studies, draw block diagrams and describe function of each subsystem.

VIII. Computer Data Analysis and Display

A. Units of Instruction

1. Fundamentals of digital computer operation
2. Data reduction
    a. Selection of regions of interest
    b. Background subtraction
    c. Smoothing
3. Display modes
    a. Contour
    b. Isomeric
    c. Slices

B. Laboratory Projects

1. Given manuals for computers used in NMT, draw block diagrams, label and describe function of each subsystem.
2. Given computer and magnetic tape of a clinical procedure, display data in as many modes as possible.

Texts and References

Beck and Gottschalk. Fundamental Problems in Scanning

Behrens, King, and Carpenter. Atomic Medicine

Blahd. Nuclear Medicine

Chase and Rabinowitz. Principles of Radioisotope Methodology

Croll and Brady. Recent Advances in Nuclear Medicine

Croll, Brady, Tatem, and Honda. Clinical Dynamic Function Studies with Radionuclides

Early, Razzak, and Sodee. Textbook of Nuclear Medicine Technology

Freeman and Johnson. Clinical Scintillation Scanning

Hine. Instrumentation in Nuclear Medicine, Vol. 1.

International Atomic Energy Agency. Medical Radioisotope Scanning, Vol. 2

International Atomic Energy Agency. Medical Radioisotope Scintigraphy, Vol. 1

Kramer and Gemmil, eds. Experiments in Nucleonics

Maynard. Clinical Nuclear Medicine

National Bureau of Standards. Progress in Medical Radioisotope Scanning

Price. Nuclear Radiation Detection

Quimby, Feitelberg, and Gross. Radioactive Nuclides in Medicine and Biology

Simmons. A Training Manual for Nuclear Medicine Technologists

Southeastern Chapter of Nuclear Medicine. Continuing Education Lectures; A Review of Nuclear Medicine

Wagner. Principles of Nuclear Medicine

NUCLEAR INSTRUMENTATION II

I. TYPES OF IMAGING SYSTEMS

A. The student should be able to:

1. Identify the essential components of a general imaging system including:
    a. Detector or detectors
    b. High voltage power supply
    c. One or more single-channel analyzers
    d. Electronics for data manipulation
    e. One or more data displays.

2. Describe construction of a typical rectilinear scanner, including, in addition to the above:
    a. The relative advantages and disadvantages of typical crystal sizes
    b. The means by which the detector, roster, or detectors are moved in a scanning roster
    c. The presence of meters for determining detector count rate and/or information density
    d. The means for displaying the data by photo-recording, mechanical tapper or cathode ray oscilloscope.

3. Describe the essential features of an Anger type camera, including as a minimum:
    a. Typical crystal dimensions
    b. The presence of 19 or more photomultiplier tubes
    c. Positioning circuitry which determines the position of the γ- ray interaction in the crystal by comparing the outputs of a number of photo-multiplier tubes
    d. The reason for the "inherent resolution" of the system, and its variation with γ- ray energy and crystal thickness
    e. Formation of the image on a cathode ray oscilloscope in terms of the X and Y position pulses.

4. Compare, qualitatively, the relative sensitivity of the rectilinear scanner and Anger camera to:
    a. A point source of radioactivity
    b. A plane source of radioactivity.

II. PHOTOGRAPHIC FILM PROCESSING

A. The student should be able to:

1. Describe the chemical structure and nature of film.

2. Discuss the mechanisms of exposure.

II. PHOTOGRAPHIC FILM PROCESSING (continued)

3. Compare the response to wave length/color of "X-ray" film, orthochromatic film, and panchromatic film.

4. Describe the basic processes of chemical image evolvement. This should include development, fixing, and washing.

5. Discuss the effect of focal length on image size and lens "speed."

6. Describe the control of light transmission. The description should include the role of iris diaphrams, "f" numbers, and relative light values.

7. Describe the nature and construction of compound lenses.

8. Define chromatic aberration and astigmatism.

9. Discuss the intensity-time relationships for constant exposure. Proper response should draw analogy to Ma/sec X-ray exposure.

10. Compare manual vs automatic film processing techniques.

III. COLLIMATION

A. The student should be able to:

1. Describe qualitatively the functions of various collimators, including focusing collimators for rectilinear scanners and parallel hole collimators for stationary imaging devices. The description must include the concept of limiting the field of view of the detector to a specific region of the patient's body.

2. Describe the geometric characteristics of a given collimator. The description must include the components of the collimator's field of view and how this is influenced by collimator design.

3. Describe the interrelationship of sensitivity (geometrical efficiency) and resolution for both focused and parallel-hole collimators.

4. Describe the governing elements of collimator efficiency (for extended sources). The list must include collimator radius of resolution, transmission, detector diameter, collimator length, and focal depth.

III. COLLIMATION (continued)

5. Describe qualitatively the way in which spatial resolution changes with distance from the face of a focusing collimator, as compared with the changes in distance from the face of a parallel-hole collimator. The student must explain the difference in terms of the geometric designs of the two collimators.

6. Describe the properties of a pin-hole collimator and show by means of a diagram how the hole diameter affects resolution, image magnification, and collimator efficiency (sensitivity).

7. Describe why penetraiton of collimator material by gamma photons is undesirable.

8. Describe a means of showing excessive septal penetration by examination of an image.

9. List four methods of reducing septal penetration by collimator design and use. The list must include:
   a. Use of material with higher attenuation coefficients
   b. Increase of septal thickness
   c. Increase of collimator length
   d. Use of the collimator with gamma photos of sufficiently low energy that penetration is not significant.

10. Given a description of a clinical scanning situation, select the proper collimator for a given imaging device and justify its selection to fit that particular situation.

IV. PARAMETERS OF IMAGING SYSTEMS

A. The student should be able to:

1. Discuss the efficiency (sensitivity) of an imaging device by describing the components of the system that determine its sensitivity. The efficiencies of the collimators used in an NaI(Tl) crystal, or crystals must be described relative to the contribution to the total system sensitivity. The description must also include the effects of pulse height analyzer window widths for both rectilinear scanners and stationary imaging devices.

2. Describe the spatial resolving ability of a system by listing the components that affect resolution and how they cause their effect. The following components should be included: collimator, detector, photomultiplier circuit, amplifier, analyzer window width, data manipulation electronics (effect of ratemeter, if any), and film response.

IV. PARAMETERS OF IMAGING SYSTEMS (continued)

3. Describe the effect on resolution of photon scatter within the patient. The description must state how these effects may be minimized by appropriate instrument adjustment.

4. Describe uniformity of response and linearity in stationary imaging devices. Included must be a discussion of the characteristics of an acceptable response, the importance of uniformity and linearity, and monitoring procedures.

5. Describe the upper limit on count rates, including dead time and its determination.

6. Describe the importance of dead time in a system. Dead time should be described with regard to loss of data in rectilinear and stationary imaging devices, and within these systems the source for data loss must be identified.

7. Describe the importance of dead time when recording rapidly occurring physiologic processes.

8. Describe, for any given imaging system, the apparent loss of spatial resolution due to statistical fluctations from insufficient count rates. Included must be a qualitative or conceptual description of means of achieving specified count densities in a clinical study with the imaging system under discussion. Additionally, the description should include acceptable ranges of count densities for different organ images with the system in question.

9. Describe the important parameters of image production on rectilinear scanners.

10. Describe the importance of count density control with relation to apparent resolution and technical quality of scans and images.

11. Describe the steps for obtaining an image with a specified count density at a point corresponding to a specific anatomic location. To be acceptable, the description must include the interrelationship between count rate, scanning speed, line spacing, desired count density, and film exposure factors. The description must describe what adjustments to make given changing parameters.

12. Describe the effects of line spacing and aperture size on the cosmetic quality of scan images.

13. Describe contrast enhancement and its applications to scanning. To be acceptable, the description must include the relationship between film blackness and counting rate, which

IV. PARAMETERS OF IMAGING SYSTEMS (continued)

may be shown by means of a diagram illustrating specific contrast enhancement schemes.

14. Describe background erase in the same manner given in the above objective.

15. Describe the effect of delayed response due to ratemeter time constants and exposure-modulation circuits on the scan image. To be acceptable, the description must include identification of "scalloping" as the result of excessively delayed response and must also include the effect of insufficient smooting time constants. The description must also include reduction of rate meter effect by proper choice of scanning speed.

16. Describe image production on stationary imaging devices.

17. Describe a means of prospectively setting display oscilloscope intensity to provide a proper film exposure when the total image count has been pre-set.

18. Describe adjustments of the exposure factors when differing pre-set counts and pre-set times.

V. RESOLUTION DETERMINATION IN IMAGING SYSTEMS

A. The student should be able to:

1. Describe the use of a point source to determine collimator resolution. The description must include the technique for obtaining isoresponse curves.

2. Describe the use of a line source in determining collimator resolution. The method of obtaining line spread functions must be included.

3. Describe FWHM as an index of instrument resolution determined from line spread and point spread functions.

4. Describe how, in the absence of excessive septal penetration and scatter within the patient, both point speed and line speed functions contain adequate indications of spatial resolution.

5. Where the conditions of objective #4 are not met, describe evidence of poor resolution seen in both PSP and LSF.

VI. INSTRUMENTATION QUALITY CONTROL

A. The student should be able to:

1. Describe the necessity for and methods of, "calibrating" a scintillation detector system. To be acceptable the following items must be included; determination of operating voltage and gain and use of a proper window width.

2. Describe the necessity for and methods of daily operating checks including standard source counting, background monitoring, record keeping, and the maintenance of a statistical quality control chart on each counting instrument.

3. Describe a means for the determination of energy resolution (line width) of scintillation detectors used for gamma counting. To be acceptable, description must state the maximum range of acceptable line widths for energy-selective counting.

4. Describe the necessity for and methods of obtaining daily flood source and bar phantom images to check uniformity and linearity of response.

5. Given a source with a specific gamma ray energy, describe the procedure for determining window settings of a rectilinear scanner, both in calibration and broad-window counting situations. To be acceptable, the description must include the determination of both the lower and upper discrimination levels and the proper performance of the system as denoted by an expected counting rate from a given source.

6. Given the same situation described above for a scintillation camera, describe a means of adjusting the energy acceptance window to a proper width, including a means of proof of the proper setting (spectrum monitor photo).

VII. RECORDING EQUIPMENT FOR DYNAMIC STUDIES

A. The student should be able to:

1. Describe the operation of auxiliary instrumentation used to record and retrieve dynamic function data including dynamic imaging. The description should make reference to the following:
   a. The basic considerations of magnetic tape storage and retrieval of simple event (analog) dynamic function data, including the concept of nonreal-time playback and the influence of any ratemeter, digital ratemeter, and strip chart recorder on the information retrieval.

VII. RECORDING EQUIPMENT FOR DYNAMIC STUDIES (continued)

b. The magnetic tape storage and retrieval of digital information, including digital image data, the concept of essential data loss, and the limitation of real-time playback.

c. The retrieval of data from selected regions of interest in dynamic image data, the influence of any rate device used, and the statistical considerations of count density within the regions of interest.

d. The operating considerations of automatic photographic equipment for sequenced film image production from display devices, including the operation of at least 35mm equipment and should be applicable to cine and 70mm systems.

VIII. COMPUTER DATA ANALYSIS AND DISPLAY

A. The student should be able to:

1. Describe the differences between an analog and a digital computer.

2. Given a decimal number, convert it into a binary number.

3. List and explain the function and interrelation of a digital computer's building blocks. The response must include the input, control unit, arithmetic unit, memory, and output.

4. List applications of digital computers which are connected to gamma cameras. The response must include data reduction and display, background subtraction and data smoothing.

5. List common display modes and applications for each. These modes must include contours, isometric views and slices.

CLINICAL PRACTICUM I

Hours Required

Hospital, 14

Course Description

Practical experience in the fundamental techniques of nuclear medicine technology is presented in three clinical practicums conducted at a hospital nuclear medicine facility. During the three practicums, the student will spend several days a week in a hospital observing the ongoing activities of a nuclear medicine facility and the examinations and procedures performed. Under the guidance of clinical instructors, the first clinical practicum will provide the student with a foundation for establishing relationships between the concepts presented in CLINICAL NUCLEAR MEDICINE TECHNOLOGY I and his observations within the hospital.

Upon completion of this practicum, students should have observed all of the topic-related activities for each type of examination and therapeutic procedure. Students should also be able to describe the administrative and nursing care procedures practiced in a nuclear medicine facility.

Major Divisions		Semester Class Hours
I.	Administrative Procedures	7
II.	Nursing Procedures	7
III.	Cardiovascular Examinations	25
IV.	Gastrointestinal Examinations	25
V.	Renal Examinations	25
VI.	Hematological Examinations	25
VII.	Endocrine/Exocrine Examinations	25
VIII.	Neurological Examinations	25
IX.	Skeletal and Soft Tissue Examinations	25
X.	Body Composition Examinations	10
XI.	Therapeutic Procedures	11
	Total	210

I. Administrative Procedures

A. Review a hospital or departmental operations manual.

B. Review examination requisitions and identify their basic components.

C. Review the daily work schedule.

D. Review departmental forms including radiation safety, radionuclide disposition, and instrument performance records.

E. Review interhospital supply requisitions.

II. Nursing Procedures

A. Review patient charts.

B. Observe techniques for moving patients of varying conditions.

C. Observe a suction apparatus.

D. Observe techniques for obtaining temperature, blood pressure, and respiration.

E. Observe techniques for administering oxygen.

F. Observe emergency kit and identification of its contents.

III. Cardiovascular Examinations

A. Observe patient charts and laboratory data. Identify indications for performing lung scan examinations.

B. Observe patient requisitions for lung scan examinations.

C. Observe patients being interviewed for lung scan examinations.

D. Observe calculation, drawing up, calibration, and administration of radiopharmaceutical doses for lung scan examinations.

E. Observe techniques of moving and positioning patients when performing lung scan examinations.

F. Observe the process of setting instrument techniques when performing lung scan examinations.

G. Observe scans and scintiphotos which make up the lung scan examination.

H. Observe quality control review of lung scan examination results.

I. Observe completion of required forms and records including consent forms, radiation administration records, etc.

J. Observe discharge of patients from the nuclear medicine facility.

Observe all the above activities for performing ventilation examinations, blood pool examinations, dynamic cardiopulmonary examinations, and cardiac examinations.

IV. Gastrointestinal Examinations

A. Observe patient charts and laboratory data. Identify indications for performing liver scan examinations.

B. Observe patient requisitions for liver scan examinations.

C. Observe patients being interviewed for liver scan examinations.

D. Observe calculation, drawing up, calibration, and administration of radiopharmaceutical doses for liver scan examinations.

E. Observe techniques of moving and positioning patients when performing liver scan examinations.

F. Observe the process of setting instrument techniques when performing liver scan examinations.

G. Observe scans and scintiphotos which make up the liver scan examination.

H. Observe quality control review of liver scan examination results.

I. Observe completion of required forms and records including consent forms, radiation administration records, etc.

J. Observe discharge of patients from the nuclear medicine facility.

Observe all of the above activities for performing liver function examinations (Rose Bengal studies), and pancreas examinations.

K. Observe calculation and administration of radiopharmaceutical doses, preparation of samples and standards, counting of samples and standards, and calculation of test results for GI loss studies and other gastrointestinal examinations.

V. Renal Examinations

A. Observe patient charts and laboratory data. Identify indications for performing renal scan examinations.

B. Observe patient requisitions for renal scan examinations.

C. Observe patients being interviewed for renal scan examinations.

D. Observe calculation, drawing up, calibration, and administration of radiopharmaceutical doses for renal scan examinations.

E. Observe techniques of moving and positioning patients when performing renal scan examinations.

F. Observe the process of setting instrument techniques when performing liver scan examinations.

G. Observe scans and scintiphotos which make up the renal scan examination.

H. Observe quality control review of renal scan examination results.

I. Observe completion of required forms and records including consent forms, radiation administration records, etc.

J. Observe discharge of patients from the nuclear medicine facility.

Observe all of the above activities for performing kidney function studies (renograms) and renal flow studies.

VI. Hematological Examinations

A. Observe patient charts and laboratory data. Identify indications for performing spleen scan examinations.

B. Observe patient requisitions for spleen scan examinations.

C. Observe patients being interviewed for spleen scan examinations.

D. Observe calculation, drawing up, calibration, and administration of radiopharmaceutical doses for spleen scan examinations.

E. Observe techniques of moving and positioning patients when performing spleen scan examinations.

F. Observe the process of setting instrument techniques when performing spleen scan examinations.

G. Observe scans and scintiphotos which make up the spleen scan examination.

H. Observe quality control review of spleen scan examination results.

I. Observe completion of required forms and records including consent forms, radiation administration records, etc.

J. Observe discharge of patients from the nuclear medicine facility.

K. Observe calculation and administration of radiopharmaceutical doses, preparation of samples and standards, counting of samples and standards, and calculation of test results for blood volume studies, RBC survival studies, B12 absorption studies, and other ferrokinetic determinations.

VII. Endocrine/Exocrine Examinations

A. Observe patient charts and laboratory data. Identify indications for performing thyroid scan examinations.

B. Observe patient requisitions for thyroid scan examinations.

C. Observe patients being interviewed for thyroid scan examinations.

D. Observe calculation, drawing up, calibration, and administration of radiopharmaceutical doses for thyroid scan examinations.

E. Observe techniques of moving and positioning patients when performing thyroid scan examinations.

F Observe the process of setting instrument techniques when performing thyroid scan examinations.

G. Observe scans and scintiphotos which make up the thyroid scan examination.

H. Observe quality control review of thyroid scan examination results.

I. Observe completion of required forms and records including consent forms, radiation administration records, etc.

J. Observe discharge of patients from the nuclear medicine facility.

Observe all of the above activities for performing salivary gland scan examinations.

K. Observe calculation and administration of radiopharmaceutical doses, preparation of samples and standards, counting of samples and standards, and calculating test results for thyroid uptake studies, thyroid suppression studies, and other thyroid gland examinations.

VIII. Neurological Examinations

A. Observe patient charts and laboratory data. Identify indications for performing brain scan examinations.

B. Observe patient requisitions for brain scan examinations.

C. Observe patients being interviewed for brain scan examinations.

D. Observe calculation, drawing up, calibration, and administration of radiopharmaceutical doses for brain scan examinations.

E. Observe techniques of moving and positioning patients when performing brain scan examinations.

F. Observe the process of setting instrument techniques when performing brain scan examinations.

G. Observe scans and scintiphotos which make up the brain scan examination.

H. Observe quality control review of brain scan examination results.

I. Observe completion of required forms and records including consent forms, radiation administration records, etc.

J. Observe discharge of patients from the nuclear medicine facility.

Observe all of the above activities for performing cisternogram examinations, and dynamic brain studies.

IX. Skeletal and Soft Tissue Examinations

A. Observe patient charts and laboratory data. Identify indications for performing bone scan examinations.

B. Observe patient requisitions for bone scan examinations.

C. Observe patients being interviewed for bone scan examinations.

D. Observe calculation, drawing up, calibration, and administration of radiopharmaceutical doses for bone scan examinations.

E. Observe techniques of moving and positioning patients when performing bone scan examinations.

F. Observe process of setting instrument techniques when performing bone scan examinations.

G. Observe scans and scintiphotos which make up the bone scan examination.

H. Observe quality control review of bone scan examination results.

I. Observe completion of required forms and records including consent forms, radiation administration records, etc.

J. Observe discharge of patients from the nuclear medicine facility.

Observe all of the above activities for performing soft tissue tumor localization examinations, and bone marrow examinations.

X. Body Composition Examinations

A. Observe calculation and administration of radiopharmaceutical doses, preparation of samples and standards, counting of samples and standards, and calculating test results for body composition examinations.

XI. Therapeutic Procedures

A. Observe patient charts and laboratory data. Identify indications for performing therapeutic procedures.

B. Observe patient consults for therapeutic procedures.

C. Observe patients being interviewed for therapeutic procedures.

D. Observe calculation and administration of radiopharmaceutical doses for therapeutic procedures.

E. Observe completion of required forms and records including consent forms, radiation administration records, etc.

F. Observe discharge of patients from the nuclear medicine facility.

Texts and References

See CLINICAL NUCLEAR MEDICINE TECHNOLOGY I

Additional References

NMT Department's Procedure Manual

Manufacturers' Instruction Manuals for NMT equipment.

CLINICAL NUCLEAR MEDICINE TECHNOLOGY I

Hours Required

Class, 3; Laboratory, 2

Course Description

CLINICAL NUCLEAR MEDICINE TECHNOLOGY I is the first of a two-semester course which is designed to follow a didactic approach to clinical nuclear medicine technology. A considerable number of class hours are allotted to the review of concepts in anatomy, physiology, pathology, and radiopharmaceuticals as they relate to the clinical procedures outlined in the main topics.

The student is taught why a particular nuclear medicine exam is requested, how to recognize a good nuclear medicine image, and how to analyze test data. These concepts are reinforced by companion laboratory exercises. The practical aspects of nuclear medicine examination techniques are taught during the second semester of CLINICAL NUCLEAR MEDICINE TECHNOLOGY II.

Insofar as the bulk of material presented in this course does not require special classroom or laboratory facilities, it may be taught on the college campus. Equipment in the campus basic instrumentation laboratory will be adequate for the elementary procedures presented in this course.

Upon completion of NUCLEAR MEDICINE TECHNOLOGY I students should be able to describe the basic physiologic mechanisms pertinent to nuclear medicine examinations; to understand why a specific test is indicated; which radiopharmaceutical is preferred; and how the basic image appearance and/or numerical data may be altered by specific pathologic states.

Major Divisions

		Semester	
		Class Hours	Lab Hours
I.	Administrative Procedures	5	2
II.	Nursing Procedures	4	2
III.	Clinical Procedures - Pulmonary Cardiovascular	4	2
IV.	Clinical Procedures - Gastrointestinal	4	4
V.	Clinical Procedures - Renal	4	2
VI.	Clinical Procedures - Hematological	4	5
VII.	Clinical Procedures - Endocrine/Exocrine	4	3
VIII.	Clinical Procedures - Neurological	4	4
IX.	Clinical Procedures - Skeletal and Soft Tissue	5	2
X.	Clinical Procedures - Body Composition	4	2
XI.	Clinical Procedures - Therapeutic Uses	4	2
	Total	45	30

I. Administrative Procedures

A. Units of Instruction

1. Hospital and departmental policies
2. Referral procedures and requisition processing
3. Scheduling of patients
4. Organizing patient examination data
5. Radiation safety records
6. Records of radionuclide accountability
7. Inventory procedures
8. Instrument performance records
9. Sources of supplies

B. Laboratory Projects

1. Organize a prototypical hospital or departmental operations manual.
2. Develop a sample nuclear medicine examination requisition.
3. Develop a patient schedule for a one-week examination load in a nuclear medicine facility.
4. Set up procedures for maintaining files of records on radiation safety, patient examination results, instrument performance, recept and disposition of radiopharmaceuticals, and laboratory equipment and supplies.

II. Nursing Procedures

A. Units of Instruction

1. The patient chart (hospital record, medical record)
2. Moving the patient
3. Temperature, blood pressure, and respiration
4. Oxygen, IVs, and catheters
5. Suction
6. Emergencies
7. Medication orders
8. Patient precautions and infectious diseases

B. Laboratory Projects

1. Review a sample patient chart and identify and locate relevant types of data.
2. Participate in moving a "student patient" of varying physical conditions.
3. Perform techniques of obtaining temperature, blood pressure, and respiration with a "student patient."
4. Practice working with a suction apparatus identifying its components and describing their maintenance.

III. Clinical Procedures - Pulmonary Cardiovascular

A. Units of Instruction

1. Review of anatomy
2. Review of physiology
3. Review of pathology
4. Lung images (perfusion and ventilation)
   a. Indications
   b. Appearance
   c. Radiopharmaceuticals
5. Blood pool images
   a. Indications
   b. Appearance
   c. Radiopharmaceuticals
6. Pulmonary Cardiovascular hemodynamic studies (flow studies)
   a. Indications
   b. Appearance and data analysis
   c. Radiopharmaceuticals
7. Cardiac images (myocardial and coronary)
   a. Indications
   b. Appearance and data analysis
   c. Radiopharmaceuticals

B. Laboratory Projects

1. Handle, observe, and identify parts of anatomical models of the heart and lungs.
2. Locate and correlate specified data in sample patient charts with sample lung perfusion and ventilation, cardiac, and blood pool examination requisitions.
3. Observe and identify normal and abnormal patterns of radiopharmaceutical distribution on lung perfusion and ventilation, cardiac, and blood pool scans and scintiphotos.
4. Locate and correlate specified data in sample patient charts with sample hemodynamic examination requisitions.
5. Observe and identify normal and abnormal patterns of blood flow obtained from hemodynamic studies.
6. Plot numerical data and analyze results of hemodynamic studies.

IV. Clinical Procedures - Gastrointestinal

A. Units of Instruction

1. Review of anatomy
2. Review of physiology
3. Review of pathology
4. Liver images
   a. Indications
   b. Appearance and data analysis
   c. Radiopharmaceuticals
5. Liver function studies (Rose Bengal studies)
   a. Indications
   b. Appearance and data analysis
   c. Radiopharmaceuticals
6. Pancreas images
   a. Indications
   b. Appearance
   c. Radiopharmaceuticals
   d. Patient pre-examination preparation
7. Absorption and GI loss studies
   a. Indications
   b. Results and data analysis
   c. Technique

B. Laboratory Projects

1. Observe, handle, and identify parts of anatomical models of the liver, spleen, and pancreas.
2. Locate and correlate specified data in sample patient charts with sample liver and pancreas examination requisitions.
3. Observe and identify normal and abnormal patterns of radiopharmaceutical distribution on liver and pancreas scans and scintiphotos.
4. Observe effects of radiographic procedures such as barium enemas on the appearance of liver scans and scintiphotos, and dietary effects on the appearance of pancreas scans and scintiphotos.
5. Locate and correlate specified data in sample patient charts with sample liver function tests and GI loss examination requisitions.
6. Plot numerical data and analyze results of liver function and GI loss studies.

V. Clinical Procedures - Renal

A. Units of Instruction

1. Review of anatomy
2. Review of physiology
3. Review of pathology
4. Kidney images
    a. Indications
    b. Appearance
    c. Radiopharmaceuticals
5. Kidney function studies (renogram)
    a. Indications
    b. Appearance and data analysis
    c. Radiopharmaceuticals
6. Renal hemodynamic studies (flow studies)
    a. Indications
    b. Appearance and data analysis

B. Laboratory Projects

1. Observe, handle, and identify parts of an anatomical model of the kidney.
2. Locate and correlate specified data in sample patient charts with sample renal scan examination requisitions.
3. Observe and identify normal and abnormal patterns of radiopharmaceutical distribution on renal scans and scintiphotos. Discuss effects of renal transplantation on the appearance of the renal scan and scintiphoto.
4. Locate and correlate specified data in sample patient charts with sample renal function examination requisitions and sample hemodynamic examination requisitions.
5. Observe and identify normal and abnormal data obtained from renal function and renal hemodynamic examinations.
6. Plot numerical data and analyze results of renal function and renal hemodynamic examinations.

VI. Clinical Procedures - Hematological

A. Units of Instruction

1. Review of anatomy
2. Review of physiology
3. Review of pathology
4. Spleen images
    a. Indications
    b. Appearance
    c. Radiopharmaceuticals
5. Blood volume and RBC survival studies
    a. Indications
    b. Technique
    c. Results and data analysis
6. B_{12} absorption and other ferrokinetic studies
    a. Indications
    b. Technique
    c. Results and data analysis

B. Laboratory Projects

1. Observe, handle, and identify parts of an anatomical model of the spleen.
2. Locate and correlate specified data in sample patient charts with a sample spleen scan examination requisition.
3. Observe and identify normal and abnormal patterns of radiopharmaceutical distribution on spleen scans and scintiphotos.
4. Observe demonstration on drawing blood.
5. Observe and identify components of blood samples which have layered in sample tubes.
6. Examine samples of blood microscopically and identify major anatomical components.
7. Observe techniques for performing selected basic ferrokinetic studies.
8. Tabulate and analyze sets of sample test data from selected ferrokinetic studies.

VII. Clinical Procedures - Endocrine/Exocrine

A. Units of Instruction

1. Review of anatomy
2. Review of physiology
3. Review of pathology
4. Thyroid uptake and suppression studies
    a. Indications
    b. Technique
    c. Results and data analysis
5. Thyroid images
    a. Indications
    b. Appearance
    c. Radiopharmaceuticals
6. Salivary gland images
    a. Indications
    b. Appearance
    c. Radiopharmaceuticals

B. Laboratory Projects

1. Observe, handle, and identify parts of anatomical models of the thyroid, parathyroid, and salivary glands.
2. Locate and correlate specified data in sample patient charts with sample thyroid, parathyroid, and salivary gland examination requisitions.
3. Observe and identify normal and abnormal patterns of radiopharmaceutical distribution on thyroid, parathyroid, and salivary gland scans and scintiphotos.
4. Discuss effects of nonradioactive iodine on thyroid scans.

5. Observe techniques for performing selected thyroid function studies.
6. Observe effects of nonradioactive iodine on thyroid function studies.
7. Tabulate and analyze sets of sample test data from selected thyroid function studies.

VIII. Clinical Procedures - Neurological

A. Units of Instruction

1. Review of anatomy
2. Review of physiology
3. Review of pathology
4. Brain images
   a. Indications
   b. Appearance
   c. Radiopharmaceuticals
5. Brain hemodynamic studies (flow studies)
   a. Indications
   b. Appearance and data analysis
   c. Radiopharmaceuticals
6. Cisternographic images
   a. Indications
   b. Appearance
   c. Radiopharmaceuticals

B. Laboratory Projects

1. Observe, handle, and identify parts of an anatomical model of the brain.
2. Locate and correlate specified data in sample patient charts with sample brain scan or cisternographic examination.
3. Observe and identify normal and abnormal patterns of radiopharmaceutical distribution on brain and cisternographic scans and scintiphotos.
4. Locate and correlate specified data in sample patient charts with sample brain hemodynamic examination requisitions.
5. Observe and identify normal and abnormal patterns of radiopharmaceutical distribution as well as numerical data obtained from brain hemodynamic examinations.
6. Plot sets of sample numerical test data and analyze results of brain hemodynamic examinations.

IX. Clinical Procedures - Skeletal and Soft Tissue

A. Units of Instruction

1. Review of anatomy
2. Review of physiology
3. Review of pathology
4. Bone images
   a. Indications
   b. Appearance
   c. Radiopharmaceuticals
5. Tumor localization images
   a. Indications
   b. Appearance
   c. Radiopharmaceuticals
6. Bone marrow images
   a. Indications
   b. Appearance
   c. Radiopharmaceuticals
7. Bone density studies
   a. Indications
   b. Results and data analysis

B. Laboratory Projects

1. Observe, handle, and identify major parts of a skeleton, and identify primary primary sites of bone marrow production. Observe and identify same features on companion X-rays.
2. Locate and correlate specified data in sample patient charts with sample bone, bone marrow, and soft tissue examination requisitions.
3. Observe and identify normal and abnormal patterns of radiopharmaceutical distribution on bone, bone marrow, and soft tissue examinations.
4. Identify and describe functions of the major components of a bone mineral analyzer.
5. Plot sets of sample numerical test data and analyze results of bone densitometry examinations.

X. Clinical Procedures - Body Composition

A. Units of Instruction

1. Review of anatomy
2. Review of physiology
3. Review of pathology
4. Total body and extracellular water studies
   a. Indications
   b. Technique
   c. Results and data analysis

B. Laboratory Projects

1. Locate and correlate specified data in sample patient charts with sample body composition examination requisitions.
2. Observe techniques for performing selected examinations.
3. Plot sets of sample numerical test data and analyze results of selected examinations.

XI. Clinical Procedures - Therapeutic Uses

A. Units of Instruction

1. Review of anatomy
2. Review of physiology
3. Review of pathology
4. Thyroid therapy
    a. Cancer
    b. Hyperthyroidism
5. Malignant hematological disorders
    a. Polycythemia vera
    b. Leukemia
6. Intracavitary

B. Laboratory Projects

1. Locate and correlate specified data in sample patient charts with sample thyroid therapy, hematological therapy, intracavitary, and other therapeutic procedure consults.
2. Observe special techniques for handling, measuring, and administering therapeutic quantities of radionuclides.
3. Discuss techniques of isolation of patients undergoing therapy using radionuclides.
4. Discuss results of using radionuclides for therapy.

Texts and References

Blahd. Nuclear Medicine

Deland and Wagner. 3-Volume Atlas of Nuclear Medicine

Maynard. Clinical Nuclear Medicine

Quimby. Safe Handling of Isotopes in Medical Practice

Quimby et al. Radioactive Nuclides in Medicine and Biology - Instrumentation

Silver. Radioactive Nuclides in Medicine and Biology - Medicine

Sodee and Early. Technology and Interpretation of Nuclear Medicine Procedures

Wagner. Principles of Nuclear Medicine

PERFORMANCE OBJECTIVES FOR CLINICAL NUCLEAR MEDICINE TECHNOLOGY I

I. ADMINISTRATIVE PROCEDURES

A. The student should be able to:

1. Explain the rationale for maintaining an Operaton/Procedures manual. The explanation should include reference to state and federal regulatory agencies.

2. Outline the content of a departmental operations manual. To be acceptable, the outline must include instrumentation calibration and maintenance, radiopharmaceutical calibration, and administration and examination techniques.

3. Given an examination requisition, develop a flow diagram representing the processing and distribution of the requisition parts. To be acceptable, flow diagram must include nuclear medicine files, patient record, referring physician, and accounting department.

4. Describe how data from the examination requisition may be used to develop a system for the compilation of departmental statistics.

5. Given a number of examination requisitions, develop an efficient production schedule. To be acceptable, schedule must resolve conflicts of multiple examinations on the same patient and must include downtime, maintenance time, and calibration time allowances for all instruments.

6. Identify all components of the patient nuclear medicine examination record.

7. Identify different types of radiation safety records. Responses should include personnel area surveys, and patient data.

8. Identify data required to fulfill responsibility of radionuclide accountability. To be acceptable, response must include data, isotope, lot number, activity, examination, dose, and volume.

9. Identify instrument test procedures essential to the instrument performance record. To be acceptable, procedures must include percent resolution, field uniformity, and detector sensitivity.

10. Develop a flow diagram representing the process of ordering, receiving, and purchasing supplies. The process should

I. ADMINISTRATIVE PROCEDURES (continued)

include appropriate forms, administrative approvals, as well as a description of the functions performed by the purchasing, receiving, and accounting departments.

II. NURSING PROCEDURES

A. The student should be able to:

1. Extract specified patient data from the medical record. To be acceptable, data extracted must include admission data, laboratory reports, and X-ray reports.
2. Given temperature in Farenheit degrees, convert to Centigrade degrees. To be acceptable, conversion must employ correct formula.
3. Convert pounds to kilograms.
4. Describe the difference between diastolic and systolic pressures.
5. Describe possible complications arising from injecting radiopharmaceuticals through IVs and CVPs.
6. Demonstrate how to clean and maintain a suction apparatus.
7. Describe hospital procedures for reporting patient emergencies.
8. Given a patient medical record, identify medications that the patient has received.
9. Define reverse precautions, and other types of patient precautions.
10. Describe difference between petit and grand mal seizures.

III. CLINICAL PROCEDURES - CARDIOVASCULAR AND PULMONARY

A. The student should be able to:

1. Locate the lower lobes, the middle lobe, and the upper lobes of the lungs given an anatomical model.
2. Describe the pathway through which blood travels from the right to left side of the heart. To be acceptable, description must include veins, veinules, venous capillaries, arterial capillaries, arterioles, and arteries.
3. Define the term "capillary blockade."

III. CLINICAL PROCEDURES - CARDIOVASCULAR AND PULMONARY (continued)

4. Define the terms "pulmonary embolus" and "coronary infarct."
5. Define the term "pericardial effusion."
6. Distinguish between macroaggregates and microaggregates. To be acceptable, response must include particle size.
7. Describe the difference between ventilation and perfusion.
8. Identify three radiopharmaceuticals that may be used to obtain lung scans and scintiphotos.
9. Identify two radiopharmaceuticals that may be used to obtain blood pool scans and scintiphotos.
10. Define the term "ejection fraction."

IV. CLINICAL PROCEDURES - GASTROINTESTINAL

A. The student should be able to:

1. Describe the difference between Kupffer and polygonal cells. To be acceptable, definition must include function.
2. Identify three types of pathology which may result in a positive liver scan.
3. Identify two radiopharmaceuticals which may be used to obtain scans and scintiphotos.
4. Explain how a barium enema may interfere with a liver scan examination performed with ^{99m}Tc. To be acceptable, explanation must include gamma ray attenuation.
5. Describe the pathway of excretion of bile.
6. Describe the difference between intra-and extrahepatic obstruction.
7. Describe the major function of the spleen.
8. Identify two radiopharmaceuticals which may be used to obtain scans and scintiphotos of the spleen.
9. Explain how the spleen scan may be used to monitor the progress of another disease.
10. Explain why a special pre-examination diet is often prescribed for a patient who is going to have a pancreas scan.

IV. CLINICAL PROCEDURES - GASTROINTESTINAL (continued)

  11. Explain the subtraction technique often used in pancreas scan examinations.

V. CLINICAL PROCEDURES - RENAL

  A. The student should be able to:

    1. Identify the most common renal disease for which renograms and renal scans are requested.
    2. Identify the surface landmarks which are useful in locating a patient's kidneys.
    3. Describe the pathway of production and excretion of urine.
    4. Describe essential hypertension.
    5. Define the term "BUN." The definition should include the importance of this value when performing isotropic renal studies.
    6. Define the term "IVP."
    7. Identify two radiopharmaceuticals which may be used to obtain scans and scintiphotos of the kidneys.
    8. Describe the difference between a renal scan and renogram.
    9. Describe how the location of the transplanted kidney usually differs from that of a normal kidney.
    10. Define the term "ectopic kidney."

VI. CLINICAL PROCEDURES - HEMATOLOGICAL

  A. The student should be able to:

    1. Identify three indications for performing a blood volume determination.
    2. Identify two radiopharmaceuticals which may be used in performing blood volume determinations.
    3. Demonstrate understanding of, and ability to use, the equation for determining blood volumes.
    4. Identify units in which blood volumes are usually reported.

VI. CLINICAL PROCEDURES - HEMATOLOGICAL (continued)

5. Specify the normal range of values for blood volume determinations.
6. Define the term "intrinsic factor."
7. Identify the most common disease associated with abnormal levels of vitamin B_{12} absorption.
8. Identify two isotopes which may be used for performing Shilling tests.
9. Describe the preparation of patients prior to performing Shilling tests.
10. Demonstrate understanding of, and ability to use the equation for determining the percent of excretion for the Shilling test.

VII. CLINICAL PROCEDURES - ENDOCRINE/EXOCRINE

A. The student should be able to:

1. Define the term "pyramidal lobe."
2. Identify three diseases of the thyroid gland which may result in a positive thyroid scan and scintiphotos.
3. Distinguish between Grave's and Plummer's diseases.
4. Identify two radiopharmaceuticals which may be used to obtain scans and scintiphotos of the thyroid gland.
5. Distinguish between the hyperthyroid, euthyroid, and hypothyroid patient. To be acceptable, response must reference characteristic percent uptake values for radioactive iodine.
6. Identify what the RAI uptake measures.
7. List four other hospital tests or patient medications that may affect the results of a thyroid scan or thyroid uptake study.
8. Demonstrate understanding of, and ability to use the equation for determining the RAI.
9. Define the term "Sjögren's Syndrome."
10. Identify the radioisotope most commonly used when performing salivary gland scans and scintiphotos.

VIII. CLINICAL PROCEDURES - NEUROLOGICAL

A. The student should be able to:

1. Define the term "blood brain barrier."
2. Define the term "choroid plexus."
3. Identify three types of pathology which may result in a positive brain scan examination.
4. Define the term "low pressure hydrocephalus."
5. Identify three external anatomical landmarks and the planar surfaces they define which may be used in positioning patients for brain scan and cisternographic examinations.
6. Describe the pathway of CSF flow, and explain how the cerebrospinal fluid examination differs from the brain scan examination.
7. Identify three radiopharmaceuticals which may be used to perform brain scan examinations.
8. Identify two radiopharmaceuticals which may be used to perform cisternographic examinations.
9. Describe a patient preparation commonly administered prior to the injection of ^{99m}Tc-pertechnetate for brain scans.
10. Identify five common views obtained when performing the brain scan examination. Describe the views.

IX. CLINICAL PROCEDURES - SKELETAL AND SOFT TISSUE

A. The student should be able to:

1. Define the term, "reticulendothelial system."
2. Identify three sites of bone marrow production.
3. Describe the physiologic process responsible for the localization of bone marrow scanning agents.
4. Identify two types of pathology which may result in a positive bone marrow exmaination.
5. Identify two radiopharmaceuticals which may be used for performing bone marrow scans.

IX. CLINICAL PROCEDURES - SKELETAL AND SOFT TISSUE (continued)

6. Identify the long bones of the skeleton.
7. Identify the major types of vertebrae.
8. Identify three radiopharmaceuticals which may be used for performing bone scan examinations.
9. Describe the physiologic process responsible for the localization of bone scanning agents.
10. Identify three types of pathology which may result in a positive bone scan examination.

X. CLINICAL PROCEDURES - BODY COMPOSITION

A. The student should be able to:

1. Describe the basic features of a total body counting system.
2. Identify the isotope of potassium most commonly used in the measurement of body potassium.
3. Define the term "lean body mass."
4. Identify the part of the body where most potassium is concentrated.
5. Identify a condition which can be studied through the measurement of body potassium.

XI. CLINICAL PROCEDURES - THERAPEUTIC USES

A. The student should be able to:

1. Define the term "oncology."
2. Define the term "neoplasm."
3. Define the term "metastatic."
4. Define the term "benign."
5. Identify two types of thyroid cancer.
6. Identify two types of hematologic cancer.
7. Distinguish between acute and chronic lukemia.

XI. CLINICAL PROCEDURES - THERAPEUTIC USES (continued)

8. Define the term "polycythemia vera."
9. Identify the radiopharmaceutical most commonly used in the administration of thyroid therapy.
10. Identify the radiopharmaceutical most commonly used in the treatment of polycythemia vera.

FUNDAMENTALS OF RADIOCHEMISTRY AND RADIOPHARMACEUTICALS

Hours Required

Class, 3; Laboratory, 3

Course Description FUNDAMENTALS OF RADIOCHEMISTRY AND RADIOPHARMACEUTICALS presents the fundamental concepts of radiopharmaceutical production including basic radiochemistry, including pyrogenicity and sterility testing, quality control procedures, radionuclide production and generator systems, mechanisms of radiopharmaceutical localization, radiopharmaceutical design, plus various procedures based on competitive binding theory.

Major Divions

		Semester Class Hours	Semester Lab Hours
I.	Radiopharmacy Introduction	1	0
II.	Toxicology Introduction	1	0
III.	Generator Systems	4	9
IV.	Tracer Concepts	2	0
V.	Tagging Compounds	3	6
VI.	Elements of Colloid Chemistry	5	6
VII.	Radiochemical Separation	4	0
VIII.	Mechanisms for Radionuclide Localization	3	3
IX.	Design Criteria for Radiopharmaceuticals	5	0
X.	Methods of Quality Control for Radiopharmaceuticals	10	12
XI.	Competitive Binding Procedures	7	9
	TOTAL	45	45

I. Radiopharmacy Introduction

A. Difference between Pharmacology and Radiopharmacology

II. Toxicology Introduction

A. Radiation Effects

III. Generator Systems

A. Units of Instruction

1. Construction
   a. Column
   b. Eluant
   c. Yield
2. Activity
   a. Growth and decay
   b. Computation of activitv
3. Advantages and disadvantages of different types of generators
4. Parent-daughter equilibrium
5. Elution
   a. Method
   b. Quality control of radionuclide

B. Laboratory Projects

1. Elution of Tin^{113}-Indium^{113m} minigenerator
2. Elution of ^{99}Mo-^{99m}Tc generator
3. Determination of half-life of an isotope
4. Parent-daughter equilibrium
5. Assay of radionuclides

IV. Tracer Concepts

V. Tagging Compounds (^{51}Cr, albumin, microspheres, iron hydroxide, etc.)

A. Units of Instruction

1. Method of tagging compounds and cells
2. Quality control

B. Laboratory Project

1. Preparation of microspheres
2. Preparation of ^{99m}Tc DTPA

VI. Elements of Colloid Chemistry

A. Units of Instruction

1. Theory of formation
   a. Emulsions
   b. Gels
   c. Suspensions
2. Tests to demonstrate existence of colloid
3. Stabilization of unstable colloids
4. Causes for destruction of colloids
5. Preparation of ^{99m}Tc sulfur colloid

B. Laboratory Projects

1. Preparation of ^{99m}Tc sulfur colloid
2. Testing for the existence of colloids

VII. Radiochemical Separation

A. Units of Instruction

1. Techniques for purification
2. Radionuclide purity

VIII. Mechanisms for radionuclide localization

A. Units of Instruction

1. Active transport
2. Phagocytosis
3. Capillary blockage
4. Exchange diffusion
5. Compartmental localization
6. Cell sequestration

B. Laboratory Projects

1. Determination of amount of liquid in a container.

IX. Design Criteria for Radiopharmaceuticals

- A. Units of Instruction
  - 1. Biologic behavior - biological half-life
  - 2. Toxicity
  - 3. Radiation emission
    - a. Energy
    - b. Type
    - c. Physical half-life
  - 4. Patient and critical organ dose
  - 5. Target to nontarget ratio

X. Methods of Quality Control for Radiopharmaceuticals

- A. Units of Instruction
  - 1. Radionuclide purity: spectral and auxiliary techniques
  - 2. Radiochemical purity
    - a. Chromatography
    - b. Precipitation techniques
    - c. Particle sizing
  - 3. Chemical purity tests
  - 4. Sterility: USP methods
  - 5. Antipyrogenicity techniques
- B. Laboratory Projects
  - 1. Methods of sterilizing radionuclides
  - 2. Tests for radionuclide sterility
  - 3. Test procedures for pyrogenicity
  - 4. Radiochromatography
  - 5. Determination of particle size
  - 6. Precipitation Techniques

XI. Competitive Binding Procedures

- A. Units of Instruction
  - 1. Characteristics of procedures
  - 2. Application of techniques
- B. Laboratory Projects
  - 1. Performance of radioimmunoassay
  - 2. Performance of T_3 - T_4 exams

Texts and References

Andrews. Radioactive Pharmaceuticals

Blahd. Nuclear Medicine

Blaufox and Freeman. Physicians Desk Reference for Radiology and Nuclear Medicine

Simmons. A Training Manual for Nuclear Medicine Technologists

Smith. Chromatographic and Electrophoretic Techniques

Sodee. Technology and Interpretation of Nuclear Medicine Procedures, Chapter 27

Stahl. Thin Layer Chromatography

Wagner. Principles of Nuclear Medicine

Wolf. Radiopharmaceuticals. J. Pharm. Sci.

Visual Aids

Atomic Energy Commission Film Libraries

The Atomic Pharmacy (1954)

Tagging the Atom (1954)

The Atom and the Doctor (1954)

Radiopharmaceuticals: From Reactor to Physician (1958)

20 minutes; 16 mm; color and sound

Army

The Radioisotope: Methodology (PMF-5145-D)

40 minutes

PERFORMANCE OBJECTIVES FOR FUNDAMENTALS OF RADIOCHEMISTRY AND RADIOPHARMACEUTICALS

I. RADIOPHARMACY INTRODUCTION

A. The student should be able to:

1. Describe the characteristics of pharmaceuticals, diagnostic radiopharmaceuticals, and therapeutic radiopharmaceuticals. To be acceptable, the description must include a differentiation of the response to each.

II. TOXICOLOGY INTRODUCTION

A. The student should be able to:

1. Define the term "toxicology." To be acceptable, the response must equate the quantitive effects of chemicals in biologic tissues.
2. Define the term "forensic toxicology." To be acceptable, the response must include the medical and legal aspects of the harmful effects of chemicals on humans.
3. Explain why it is necessary to conduct toxicity tests on animals before a new radiopharmaceutical is introduced for human use in the nuclear medicine laboratory.
4. Explain why it is advisable to use two animal species when performing radiopharmaceutical toxicity tests.
5. Describe the difference between acute, prolonged, and chronic toxicity tests.
6. Describe the difference between radiopharmaceutical toxicity, pyrogenicity, and sterility.
7. Explain why acute toxicity studies are usually more valuable when evaluating a radiopharmaceutical than are prolonged or chronic toxicity tests.
8. Describe the circumstances where chronic toxicity tests would be necessary in the toxicological evaluation of a radiopharmaceutical.
9. Define the term "teratogenicity."
10. Define LD_{50} as it relates to radiopharmaceutical toxicology.
11. List 5 responses which can be defined as toxicological.
12. Describe the difference between biological and structural toxicity.

III. GENERATOR SYSTEMS

A. The student should be able to:

1. Specify the matrix materials and eluants involved in the ^{113}Sn - ^{113m}In and ^{99}Mo - ^{99m}Tc generators.

2. List causes of parent radionuclide and/or column substrate (particulate or ionic) "breakthrough." To be acceptable, this must include methods of determining "breakthrough" associated with a particular generator system.

3. Given a particular generator system, describe methods for preventing "breakthrough."

4. Describe the regeneration cycles for the two equilibrium systems. To be acceptable, this must include the rate and amount of daughter radionuclide build-up related to time.

5. Regarding radioisotope generator systems, describe the parent-daughter radionuclides with both secular and transient equilibrium. To be acceptable, the description must include as examples:

   ^{113}Sn - ^{113m}IN & ^{99}Mo - ^{99m}Tc systems.

IV. TRACER CONCEPTS

A. The student should be able to:

1. Describe the purpose of tracer techniques. To be acceptable, the description must include the following uses:
   a. Clarify unknown areas of routine tests
   b. Furnish information not obtainable by other means.

V. TAGGING COMPOUNDS

A. The student should be able to:

1. Describe three methods of tagging compounds and cells. To be acceptable, these must include:
   a. The labeling of red blood cells with ^{51}Cr
   b. The preparation of technetium sulfur colloid microspheres
   c. The preparation and stability of ^{99m}Tc albumins and MAA.

VI. ELEMENTS OF COLLOID CHEMISTRY

A. The student should be able to:

1. Describe the basic theory of formation of stable emulsions, gels, and suspensions.
2. Describe what determines the particle size of colloids, micro, and macro aggregates.
3. Given a collimated light source and a centrifuge, demonstrate simple tests for the presence of colloids. To be acceptable, the demonstration must include the Tyndall cone effect, stability to centrifuging, and filterability.
4. Describe methods for the stabilization of unstable colloids by use of protective sols and by removal of ionic solutions.
5. Itemize basic causes for the destruction of colloidal systems. To be acceptable, the itemization must include destruction of heat, changes in pH, and addition of ionic salts.
6. Describe methods for preventing colloidal destruction. To be acceptable, the description must include the following steps:
   a. Maintaining temperature control
   b. Maintaining the proper pH
   c. Maintaining a low concentration of salt.
7. Describe in proper sequence the steps involved in the preparation of technetium sulfur colloid and the reasons for the steps.

VII. RADIOCHEMICAL SEPARATION

A. The student should be able to:

1. Describe the techniques which could be used in radiochemical separations which result in purer radiopharmaceuticals. To be acceptable, these techniques must include:
   a. Selective membrane filtrations for particle size determination and control
   b. Ion exchange column, and gel permeation chromatography
   c. Analytical chemistry techniques such as selective precipitation or complexing of radiochemical impurities.

VIII. MECHANISMS FOR RADIONUCLIDE LOCALIZATION

A. The student should be able to:

1. Specify mechanisms whereby radiopharmaceutical localization occurs. To be acceptable, the specification must include the following:
    - a. Active transport (ionic and non-ionic)
    - b. Phagocytosis
    - c. Capillary blockage
    - d. Exchange diffusion
    - e. Compartmental localization in single and multi-compartmental systems.

IX. DESIGN CRITERIA FOR RADIOPHARMACEUTICALS

A. The student should be able to:

1. Outline the criteria used for designing a radiopharmaceutical. To be acceptable, the outline must include:
    - a. The affinity of radiopharmaceuticals for special tissues
    - b. The retention and stability of the intact radiopharmaceutical molecule and its metabolites, e.g. released radioiodine or particles.
    - c. The comparison of the toxicity of the radiopharmaceutical with its dose.
    - d. Specification of the radionuclide characteristics such as type and energy of emission.
    - e. Control of critical organ dose by tissue specificity, amount of radionuclide needed to furnish desired information, and optimized time of measurement.
2. Given a specific diagnostic radiopharmaceutical, specify its dose limitations so as to prevent a physiological response which is due to its chemical and/or radiation properties.

X. METHODS OF QUALITY CONTROL FOR RADIOPHARMACEUTICALS

A. The student should be able to:

1. Describe techniques used to determine radionuclide purity by using a single or multichannel scintillation spectrometer. To be acceptable, the student must include the following steps in his description:
    - a. Sample preparation
    - b. Instrumentation selection
    - c. Interpretation of results.

X. METHODS OF QUALITY CONTROL FOR RADIOPHARMACEUTICALS (continued)

A. The student should be able to:

2. Describe the chemical techniques used to determine radionuclide purity. To be acceptable, the student must include analytical, chemical, bioassay, and chromatography techniques.

3. Specify potential sources of bacterial contamination.

4. Specify potential sources of pyrogenic contamination.

5. Describe routine laboratory methods for preventing bacterial contamination.

6. Describe routine laboratory methods for preventing pyrogenic contamination.

7. Describe procedures for performing sterility tests as cited in the U.S. Pharmacopeia. To be acceptable, the description must include:
   a. Thioglycolate
   b. Fluid Sabouraud media.

8. Demonstrate the U.S. Pharmacopeia pyrogen test procedures for pyrogenicity.

9. Describe basic remedies for pyrogenicity.

10. Describe basic remedies for bacterial contamination.

XI. COMPETITIVE BINDING PROCEDURES

A. The student should be able to:

1. Describe the principles underlying competitive binding procedures. To be acceptable, the description must include:
   a. Antibody-antigen relationship
   b. Labeled hormone binding
   c. Competitive binding processes and exchange reactions involved.
   d. Methods of labeling.

2. Describe four specific applications of radioimmunoassay techniques. To be acceptable, these must include insulin assay, Australian antigen, growth hormone, and renin.

SEMESTER 4

Social Psychology for the Health Sciences

Clinical Practicum II

Clinical Nuclear Medicine Technology II

Technical Reporting

SEMESTER 4

SOCIAL PSYCHOLOGY FOR THE HEALTH SCIENCES

Hours Required

Class, 3; Laboratory, 0

Course Description

SOCIAL PSYCHOLOGY FOR THE HEALTH SCIENCES is designed to assist the student in building meaningful human relationships and to help him make the adjustments necessary to develop a satisfactory work situation. The fields of adjustment to be considered are: his work environment, group interpersonal relationships, and personal involvement.

Psychologically, the student will be concerned with attitudes, frustrations, causation of behavior, motivation, individual differences, and job satisfaction. Sociologically, he will consider status, culture, role, communication, social systems, and the human relationship approach to others. He will be encouraged to see his own personality in relation to our culture and society.

Although the lecture will be used to some extent, student participation will be encouraged by role playing, case studies, practical incidents, discussion groups, conferences, and self-analysis. Emphasis will be placed upon the hospital situation with consideration of the student technician and his response to his working environment, his fellow workers, and his patients.

Major Divisions		Semester Class Hours
I.	The Application of Psychology to NMT	3
II.	Social Systems	3
III.	Attitudes	3
IV.	Causation of Behavior	6
V.	Motivation	6
VI.	Frustrations	6
VII.	The Human Relations Approach	6
VIII.	Individual Differences	3
IX.	Communications	6
X.	Insights Into New Methods of Work Satisfaction	3
	Total	45

I. The Application of Psychology to NMT

A. Units of Instruction

1. The place of Psychology in the Work Environment
    a. Selection of personnel
    b. Placement and promotion
    c. Tests and measurements
    d. Training programs
    e. Adapting machinery and job routines to man's physical and mental make-up
    f. Reduction of fatigue, boredom, accidents
    g. Human relations
    h. Mental health
2. Approaches to the use of psychology
    a. Divergent method
    b. Convergent method
    c. Laboratory method
    d. Field study method
3. Location of problems
    a. Situations
    b. Groups
    c. Individual or self
4. Knowledge for problem solving
    a. Technical
    b. Leadership
    c. Constructive attitudes

II. Social Systems

A. Units of Instruction

1. Culture
    a. Conventionalized behavior of society
    b. Manmade environment
    c. Beliefs, customs, knowledge practices
    d. Basic values
        i. Freedom
        ii. Security
        iii. Equality
        iv. Opportunity
2. Role
    a. Pattern of action expected of a person in relation to others
    b. Role perception
    c. Role set
    d. Role conflict
    e. Role ambiguity
3. Status
    a. Organizational
    b. Social
    c. Symbols or "perks"

4. Social equilibrium and personal adjustment
    a. Equilibrium
    b. Changes
    c. Adjustment versus maladjustment

III. Attitudes

A. Units of Instruction

1. Definition and terms
    a. Mental set
    b. Frame of reference
    c. Interpretation
    d. Evaluation
    e. Justification
2. What attitudes do
    a. Determine meanings
    b. Reconcile contradictions
    c. Organize facts
    d. Select facts
    e. Influence behavior
    f. Create prejudices
3. Factors influencing attitudes
    a. Likes and dislikes
    b. Emotions
    c. Physical condition
    d. Rationalization
    e. Frame of reference
    f. Personality
    g. Experience
    h. Group membership
    i. Opinions and beliefs of others
    j. Age, income, environment, education, family
4. Methods to improve attitudes
    a. Publish results of surveys
    b. Adequate use of findings
    c. Role playing
    d. Use of listening skills
    e. Use of discussion skills
    f. Communication
    g. Persuasion techniques
    h. Questionable methods - brain washing, self-criticism, propaganda, rewards, punishments

IV. Causation of Behavior

A. Units of Instruction

1. Factors influencing behavior
    a. Situation
    b. Organism
    c. Stimulation from environment
    d. Response to stimulation
2. Nature of the organism depends on:
    a. Heredity
    b. Culture
    c. Learning
    d. Intelligence
    e. Sensitivity
    f. Interests
    g. Motivations
    h. Personality
    i. Physical and emotional environment
3. The situation or stimulus situation
    a. Physical environment
    b. Other people
    c. Work routine
    d. Social factors
4. Interaction between person and the situation
    a. Perception
    b. Individual
    c. Selection
    d. Organization
    e. Interpretation
5. Solution to problems of behavior
    a. Correct the situation
    b. Improve motivation
    c. Check home problems
    d. Do not expect too much
    e. Change or improve work conditions
    f. Educate and train for O factor
    g. Modify attitudes
    h. Set up grievance procedure

V. Motivation

A. Units of Instruction

1. "All conscious behavior is caused"
    a. Human needs
    b. Incentives
2. Primary needs
    a. Basic physical
    b. Necessary for survival
    c. Preservation of the species
3. Secondary needs
    a. Social
    b. Psychological
4. Priority of needs
    a. Physiological
    b. Safety and security
    c. Belonging and social activity
    d. Esteem and status
    e. Self-realization and fulfillment
5. Motivational and maintenance needs
    a. Use Maslow's need priority model
    b. For industry use Herzberg's maintenance-motivation model
6. Incentives
    a. Money and what it represents
    b. Suggested methods of salary payment
    c. "Is there a fair way to get paid?"
    d. Fringe benefits
    e. Praise
    f. Competition
    g. Experience of achievement

VI. Frustration

A. Units of Instruction

1. Causes
    a. Pressures
    b. Repeated failures
    c. Unable to reach a goal
    d. Low frustration level
    e. Interference of another person
    f. Physical blocks
    g. Absolute necessity to solve a problem
2. Normal problem solution
    a. Acceptance of the status quo
    b. Variability
    c. Substitution
3. Frustration: A reaction to a problem
    a. Aggression
    b. Regression
    c. Fixation
    d. Resignation
    e. Defense mechanisms
4. Mental illness
    a. Neurosis
    b. Psychosis
    c. Sociopath
5. Therapy for frustrations
    a. Constructive viewpoint
    b. Correct the situation
    c. Catharsis
    d. Outlets for temporary frustrations
    e. Role playing
    f. Problem solving attitude
    g. "Face-saving"
    h. Counseling
    i. Select method suitable to individual's needs

VII. The Human Relations Approach

A. Units of Instruction

1. Meaning of human relations
2. Historical development
3. Current beliefs concerning approach
4. Fundamental concepts
    a. Individual difference
    b. Whole person
    c. Motivation
    d. Human dignity
    e. Mutuality of interest
    f. Application to patients
5. Summary
    a. Concerned with interaction of people
    b. Interaction may be social, business, political, family, clubs, schools
    c. Usually occurs in a formal structure
    d. Builds human cooperation
    e. Action and goal-oriented
    f. Fulfills need structure of the individual

VIII. Individual Differences

A. Units of Instruction

1. Nature of individual differences
    - a. Normal distribution curve
    - b. Measurement of traits
    - c. Measurement of intelligence
    - d. Sex and race differences
    - e. Variations
2. Deviations from normal curve
    - a. Bimodel
    - b. Skewed
3. Ability and performance
    - a. Performance = ability x motivation
    - b. Ability = person's potential performance
    - c. Performance = what a person actually does

IX. Communication

A. Units of Instruction

1. Definition
2. Involves two people
    - a. Sender
    - b. Receiver
3. Sender wants receiver:
    - a. To interpret
    - b. To accept ideas
    - c. To act
4. Receiver wants:
    - a. Performance
    - b. Feedback
5. Purpose of good communication
    - a. Information
    - b. Understanding
    - c. Motivation
    - d. Cooperation
    - e. Job satisfaction
    - f. Development of attitudes
6. Communication process
    - a. Ideation
    - b. Encoding
    - c. Transmission
    - d. Receiving
    - e. Decoding
    - f. Action
7. Semantics
    - a. Science of understanding
    - b. Symbolic transfer of meetings
8. Symbols of Communications
    - a. Language
    - b. Pictures
    - c. Actions
9. Barriers to communication
    - a. Environment
    - b. Psychological and emotional
    - c. Separation of inference and fact
    - d. Limitation of symbols
10. The art of listening
11. Downward communication
12. Upward communication
13. The "grape vine"
14. Rumors

X. Insights into New Methods of Work Satisfaction

A. Units of Instruction

1. Present Day Dissatisfaction

    Note: Use current media
2. Efforts to alleviate dissatisfaction
    - a. Supportive leadership
    - b. Positive motivation
    - c. Higher-need order appeals
    - d. Group-decision methods
    - e. Rewards other than economic
    - f. Recognition
    - g. Balancing human and technical values
    - h. Encouraging creativity
    - i. Decision making
    - j. Batching
    - k. "Fixit" time
    - l. Job rotation
    - m. Job enrichment
3. The student's term paper discussion
    - a. What I expect from my job
    - b. What is expected of me

4. Summary: Achievement of meaningful human relations
    a. A healthy self-image
    b. Acceptance and understanding of others
    c. Cultivation of "We're both O.K." attitude
    d. Communication person-to-person
    e. Responsibility for your decisions
    f. "A fair day's work for a fair day's pay"
    g. Development of the characteristics of flexibility, sincerity, loyalty, cooperation, integrity, and empathy

Texts and References

Davis. Human Relations at Work

Ellensen. Human Relations

Harris. I'm O.K. -- You're O.K.

Maier. Psychology in Industrial Organizations

Maslow. Motivation and Personality

May. Man's Search for Himself

Toffler. Future Shock

Visual Aids

B. W. A. Films, 5615 Fishers Lane
Rockville, Maryland 20852
Motivation Through Job Enrichment

CLINICAL PRACTICUM II

Hours Required

Hospital, 20

Course Description

Initial practical exposure to the fundamental techniques of nuclear medicine technology is presented in Clinical Practicum I. The second clinical practicum is designed to replace basic observations with actual experience in the ongoing activities of a nuclear medicine facility. During Clinical Practicum II, the student spends increasing amounts of time in the hospital nuclear medicine unit. Guided by clinical instructors, the student begins to acquire manual skills which are essential to every nuclear medicine technologist. Concepts which complement these skills are presented in Nuclear Medicine Technology II.

Students, upon completion of this practicum should have had supervised experience in performing all routine nuclear medicine examination and laboratory procedures. In addition, the student should be familiar with less frequently performed or nonroutine topic related activities.

Major Divisions		Semester Class Hours
I.	Cardiovascular/Pulmonary Examinations	28
II.	Gastrointestinal Examinations	28
III.	Renal Examinations	28
IV.	Hematological Examinations	28
V.	Endocrine/Exocrine Examinations	28
VI.	Neurological Examinations	28
VII.	Skeletal and Soft Tissue Examinations	28
VIII.	Therapeutic Procedures	14
IX.	Competitive Binding Assay Tests	90
	Total	300

I. Cardiovascular Pulmonary Examinations

A. Perform supervised scheduling of lung scan examinations.

B. Correlate relevant data from patient charts with same on lung scan examination requisitions.

C. Participate in the conduct of patient interviews for lung scan examinations.

D. Perform supervised calculation of radiopharmaceutical doses for lung scan examinations.

E. Assist with radiopharmaceutical administration for lung scan examinations.

F. Perform supervised positioning of patients for lung scan examinations.

G. Perform supervised calculation and setting of instrument techniques for lung scan examinations.

H. Participate in quality control review of lung scan examination results.

I. Perform supervised completion of required forms and records.

J. Assist with the discharge of patients from the nuclear medicine facility.

Participate in all of the above activities for performing ventilation, blood pool, dynamic cardio/pulmonary and cardiac examinations.

II. Gastrointestinal Examinations

A. Perform supervised scheduling of liver scan examinations.

B. Correlate relevant data from patient charts with same on liver scan examination requisitions.

C. Participate in the conduct of patient interviews for liver scan examinations.

D. Perform supervised calculation of radiopharmaceutical doses for liver scan examinations.

E. Assist with radiopharmaceutical administration for liver scan examinations.

F. Perform supervised positioning of patients for liver scan examinations.

G. Perform supervised calculation and setting of instrument techniques for liver scan examinations.

H. Participate in quality control review of liver scan examination results.

I. Perform supervised completion of required forms and records.

J. Assist with discharge of patients from the nuclear medicine facility.

Participate in all of the above activities for performing liver function examinations (Rose Bengal studies) and pancreas examinations.

III. Renal Examinations

A. Perform supervised scheduling of renal scan examinations.

B. Correlate relevant data from patient charts with same on renal scan requisitions.

C. Participate in the conduct of patient interviews for renal scan examinations.

D. Perform supervised calculation of radiopharmaceutical doses for renal scan examinations.

E. Assist with readiopharmaceutical administration for renal scan examinations.

F. Perform supervised positioning of patients for renal scan examinations.

G. Perform supervised calculation and setting of instrument techniques for renal scan examinations.

H. Participate in quality control review of renal scan examination results.

I. Perform supervised completion of required forms and records.

J. Assist with the discharge of patients from the nuclear medicine facility.

Participate in all of the above activities for performing kidney function studies (renograms) and dynamic renal examinations.

IV. Hematological Examinations

A. Perform supervised scheduling of spleen scan examinations.

B. Correlate relevant data from patient charts with same on spleen scan requisitions.

C. Participate in the conduct of patient interviews for spleen scan examinations.

D. Perform supervised calculation of radiopharmaceutical doses for spleen scan examinations.

E. Assist with radiopharmaceutical administration for spleen scan examinations.

F. Perform supervised positioning of patients for spleen scan examinations.

G. Perform supervised calculation and setting of instrument techniques for spleen scan examinations.

H. Perform supervised completion of required forms and records.

I. Participate in quality control review of spleen scan examination results.

J. Assist with the discharge of patients from the nuclear medicine facility.

K. Perform supervised calculation of radiopharmaceutical doses, counting of samples and standards, and calculation of test results for blood volume studies, RBC survival studies, B12 absorption studies, and other ferrokenetic determinations.

V. Endocrine/Exocrine Examinations

A. Perform supervised scheduling of thyroid scan examinations.

B. Correlate relevant data from patient charts with same on thyroid scan requisitions.

C. Participate in the conduct of patient interviews for thyroid scan examinations.

D. Perform supervised calculation of radiopharmaceutical doses for thyroid scan examinations.

E. Assist with radiopharmaceutical administration for thyroid scan examinations.

F. Perform supervised positioning of patients for thyroid scan examinations.

G. Perform supervised calculation and setting of instrument techniques for thyroid scan examinations.

H. Participate in quality control review of thyroid scan examination results.

I. Perform supervised completion of required forms and records.

J. Assist with the discharge of patients from the nuclear medicine facility.

Participate in all of the above activities for performing salivary gland examinations.

K. Perform supervised calculation of radiopharmaceutical doses, counting of samples and standards and calculation of test results for thyroid uptake studies, thyroid suppression studies, and other thyroid gland examinations.

VI. Neurological Examinations

A. Perform supervised scheduling of brain scan examinations.

B. Correlate relevant data from patient charts with same on brain scan requisitions.

C. Participate in conducting patient interviews for brain scan examinations.

D. Perform supervised calculation of radiopharmaceutical doses for brain scan examinations.

E. Assist with radiopharmaceutical administration for brain scan examinations.

F. Perform supervised positioning of patients for brain scan examinations.

G. Perform supervised calculation and setting of instrument techniques for brain scan examinations.

H. Participate in quality control review of brain scan examination results.

I. Perform supervised completion of required forms and records.

J. Assist with the discharge of patients from the nuclear medicine facility.

Participate in all of the above activities for performing cisternogram examinations and dynamic brain studies.

VII. Skeletal and Soft Tissue Examinations

A. Perform supervised scheduling of bone scan examinations.

B. Correlate relevant data from patient charts with same on bone scan requisitions.

C. Participate in conducting patient interviews for bone scan examinations.

D. Perform supervised calculation of radiopharmaceutical doses for bone scan examinations.

E. Assist with radiopharmaceutical administration for bone scan examinations.

F. Perform supervised positioning of patients for bone scan examinations.

G. Perform supervised calculation and setting of instrument techniques for bone scan examinations.

H. Participate in quality control review of bone scan examination results.

I. Perform supervised completion of required forms and records.

J. Assist with discharge of patients from the nuclear medicine facility.

Participate in all of the above activities for performing tumor localization, bone marrow, and bone densitometry examinations.

VIII. Therapeutic Procedures

A. Perform supervised scheduling of therapeutic procedures.

B. Correlate relevant data from patient charts with same on thyroid gland therapy requisitions.

C. Participate in conducting patient interviews for thyroid therapy procedures.

D. Perform supervised calculation of radiopharmaceutical doses for thyroid therapy procedures.

E. Assist with radiopharmaceutical administration for thyroid therapy procedures.

F. Perform supervised completion of required forms and records.

G. Assist with discharge of patients from the nuclear medicine facility.

Participate in all of the above activities for performing hematological and intercavitary therapeutic procedures.

IX. Competitive Binding Assay Tests

A. Participate in setting up of logs and records for patient data, test data, quality control data, isotope disposition records etc.

B. Perform supervised operation and demonstrate use of adding machines, calculators, and slide rules.

C. Perform supervised techniques of pipetting.

D. Perform supervised operation and demonstrate use of centrifuges.

E. Perform supervised operation and demonstrate use of balances, incubators, mixers, shakers, and stirrers.

F. Perform supervised measuring of solid and liquid chemical materials.

G. Perform supervised operation and demonstrate use of pH meters.

H. Perform supervised techniques of titration.

I. Perform supervised techniques of dilution.

J. Perform supervised operation and demonstrate use of liquid scintillation counting systems.

K. Participate in development and demonstrate use of standard curves.

L. Participate in calculation and reporting of test results.

Texts and References

See Clinical Practicum I

Additional References

NMT Department's Procedure Manual

Manufacturers' Instruction Manuals for NMT equipment

CLINICAL NUCLEAR MEDICINE TECHNOLOGY II

Hours Required

Class, 3; Laboratory, 0

Course Description

CLINICAL NUCLEAR MEDICINE TECHNOLOGY II is designed to provide the student with practical knowledge essential to the acquisition of skills in performing nuclear medicine examinations and tests. Each main topic provides a brief summary review of relevant information in anatomy, physiology, pathology, and radiopharmaceuticals, followed by discussions on gamma camera, rectilinear scanner, or laboratory techniques. Each topic also contains a section on applications wherein the student is encouraged to establish a logical approach in his solving of problems via sample case presentations. The sample cases teach the student to use formulas, charts, tables, and calculations in arriving at examination parameters such as the amount of dose to draw up, the number of counts to collect, the speed at which to set the instrument, etc. A number of sample cases introduce modifications in routine techniques and the effects such modifications have on the examination procedure.

The material presented in this outline does not require special classroom facilities, and the required laboratory experience will most likely take place in a hospital nuclear medicine facility where equipment and patients are readily available. For this reason, formal laboratory exercises have been omitted from this outline.

The sequence in which the main topics are presented is not critical, but optimally they will follow the practicum exercises as they are developed in the hospital environment.

Upon completion of this course and its associated clinical practicum students should be able to perform a wide variety of nuclear medicine examinations and tests using a number of different instruments without structured supervision.

Major Divisions		Semester Class Hours
I.	Clinical Procedures - Cardiovascular/Pulmonary	5
II.	Clinical Procedures - Gastrointestinal	5
III.	Clinical Procedures - Renal	5
IV.	Clinical Procedures - Hematological	4
V.	Clinical Procedures - Endocrine/Exocrine	5
VI.	Clinical Procedures - Neurological	6
VII.	Clinical Procedures - Skeletal and Soft Tissue	5
VIII.	Clinical Procedures - Therapeutic Uses	4
IX.	Clinical Procedures - Competitive Binding Assays	6
	Total	45

I. Clinical Procedures - Cardiovascular/Pulmonary

A. Units of Instruction

1. Lung perfusion images and radioaerosol images
   a. Review of anatomy, physiology, and pathology
   b. Radiopharmaceuticals
   c. Radiopharmaceutical dosage
   d. Rectilinear scanner techniques
   e. Gamma camera techniques
   f. Examination artifacts
2. Lung ventilation images
   a. Review of anatomy, physiology, and pathology
   b. Radiopharmaceuticals
   c. Radiopharmaceutical dosage
   d. Gamma camera techniques
   e. Perfusion ventilation correlation
   f. Examination artifacts
3. Blood pool images
   a. Review of anatomy, physiology, and pathology
   b. Radiopharmaceuticals
   c. Radiopharmaceutical dosage
   d. Rectilinear scanner techniques
   e. Gamma camera techniques
   f. Image/roentgenographic correlation and data analysis
   g. Examination artifacts

4. Cardiovascular pulmonary hemodynamic studies
   - a. Review of anatomy, physiology, and pathology
   - b. Radiopharmaceuticals
   - c. Radiopharmaceutical dosage
   - d. Gamma camera techniques
   - e. Data manipulation and analysis
   - f. Examination artifacts
5. Cardiac Images (myocardial and coronary)
   - a. Review of anatomy, physiology, and pathology
   - b. Radiopharmaceuticals
   - c. Radiopharmaceutical dosage
   - d. Rectilinear scanner techniques
   - e. Gamma camera techniques
   - f. Data manipulation and analysis
   - g. Examination artifacts

B. Case Studies

1. Lung images
   - a. Practice performing radiopharmaceutical dose calculations for lung examinations using appropriate formulas, tables, and charts.
   - b. Develop formats for recording radiopharmaceutical doses.
   - c. Consider how a radiopharmaceutical dose for a lung scan examination may vary with the age of the patient, weight of the patient, and radiopharmaceutical used.
2. Ventilation examinations
   - a. Consider how two different radiopharmaceuticals may be used in the same patient for related examinations; perfusion/ventilation.
   - b. Discuss gamma camera examination techniques for technetium macroaggregate perfusion followed by xenon ventilation, vs xenon ventilation followed by technetium macroaggregate perfusion.
   - c. Develop a system for removing radioactive xenon gas from the examination area.
3. Blood pool images
   - a. Discuss how a nuclear medicine blood pool image may be compared with an X-ray of the chest.
   - b. Calculate ratio of heart silhouette on a cardiac scan with the same on a chest X-ray.

II. Clinical Procedures - Gastrointestinal

A. Units of Instruction

1. Liver images
   - a. Review of anatomy, physiology, and pathology
   - b. Radiopharmaceuticals
   - c. Radiopharmaceutical dosage
   - d. Rectilinear scanner techniques
   - e. Gamma camera techniques
   - f. Examination artifacts
2. Liver function studies
   - a. Review of anatomy, physiology, and pathology
   - b. Radiopharmaceuticals
   - c. Radiopharmaceutical dosage
   - d. Rectilinear scanner techniques
   - e. Gamma camera techniques
   - f. Data analysis
   - g. Examination artifacts
3. Pancreas images
   - a. Review of anatomy, physiology, and pathology
   - b. Radiopharmaceuticals
   - c. Radiopharmaceutical dosage
   - d. Rectilinear scanner techniques
   - e. Gamma camera techniques
   - f. Patient preparation
   - g. Examination artifacts

B. Case Studies

1. Liver images
   - a. Discuss how one examination may interfere with another examination. (barium enema and technetium liver scan using relevant X-rays scans, and scintiphotos.)
   - b. Discuss how review of patient charts and interviews can reduce the number of technically unsatisfactory examinations.
2. Liver function examinations
   - a. Discuss the concept of the functional image as presented on the Rose Bengal liver examination.
   - b. Distinguish between an architectual image as presented by the Kupffer cells, and an image of function as presented by the polygonal cells on a Rose Bengal liver examination.
   - c. Develop the physiologic pathway of excretion from the liver to the gall bladder, to the gut by following a series of Rose Bengal liver scans or scintiphotos.
3. Pancreas images
   - a. Discuss the concept of preexamination diet as part of the pancreas examination technique.
   - b. Discuss methods of image enhancement by using two isotopes and employing dual counting with subtraction to more clearly delineate the pancreas from the liver on pancreas scans and scintiphotos.

III. Clinical Procedures - Renal
  A. Units of Instruction
    1. Kidney images
      a. Review of anatomy, physiology, and pathology
      b. Radiopharmaceuticals
      c. Radiopharmaceutical dosage
      d. Rectilinear scanner techniques
      e. Gamma camera techniques
      f. Examination artifacts
    2. Kidney function studies
      a. Review of anatomy, physiology, and pathology
      b. Radiopharmaceuticals
      c. Radiopharmaceutical dosage
      d. Patient preparation
      e. Gamma camera techniques
      f. Uptake probe techniques
      g. Data manipulation and analysis
      h. Examination artifacts
    3. Renal hemodynamic studies
      a. Review of anatomy, physiology, and pathology
      b. Radiopharmaceuticals
      c. Radiopharmaceutical dosage
      d. Gamma camera techniques
      e. Data manipulation and analysis
      f. Examination artifacts
  B. Case Studies
    1. Kidney images
      a. Discuss how surgical procedures require modifications in routine kidney imaging techniques in renal transplant patients.
    2. Renograms
      a. Calculate basic ratios which characterize the uptake and excretion of radiopharmaceutical as demonstrated on the renogram.
      b. Discuss how the appearance of the renogram curves may be affected by examination techniques such as patient positioning, ratemeter time constant, strip chart recorder speed, etc.
      c. Discuss effects on the renogram examination of hydrating the patient.
    3. Renal flow studies
      a. Discuss alternative formats for presenting dynamic renal studies such as polaroid, 35mm, and 70mm film.
      b. Relate different presentation formats to different instruments and techniques.
      c. Discuss the patient examination record, and identify what it should contain.
      d. Discuss development of a filing system for storing patient examination records including parameters by which exams may be filed, eg. by examination type, patient name, hospital number, etc.

IV. Clinical Procedures - Hematological
  A. Units of Instruction
    1. Spleen images
      a. Review of anatomy, physiology, and pathology
      b. Radiopharmaceuticals
      c. Radiopharmaceutical dosage
      d. Rectilinear scanner techniques
      e. Gamma camera techniques
      f. Examination artifacts
  B. Case Studies
    1. Spleen images
      a. Calculate speed at which to set the rectilinear scanner in order to obtain a specific information density on a spleen scan examination given the maximum counts per minute and line spacing. Consider how varying speed will alter the information density and the appearance of the spleen scan examination.
      b. Calculate the number of counts to be collected with the gamma camera in order to obtain a specific information density on a spleen scintiphoto given the minification value for the gamma camera oscilloscope. Consider how varying the collected number of counts will alter the information density and the appearance of the spleen scintiphoto.

V. Clinical Procedures - Endocrine/Exocrine
  A. Units of Instruction
    1. Thyroid images
      a. Review of anatomy, physiology, and pathology
      b. Radiopharmaceuticals
      c. Radiopharmaceutical dosage
      d. Rectilinear scanner technique
      e. Gamma camera techniques
      f. Examination artifacts
    2. Salivary gland images
      a. Review of anatomy, physiology, and pathology
      b. Radiopharmaceuticals
      c. Radiopharmaceutical dosage
      d. Rectilinear scanner techniques
      e. Gamma camera techniques
      f. Data manipulation and analysis

B. Case Studies
  1. Thyroid images
    a. Discuss how the voltage applied to the cathode ray tube of the rectilinear scanner changes the optical density on a thyroid scan.
    b. Consider a modification in detector voltage on the rectilinear scanner which will enhance the appearance of a pyramidal lobe on a thyroid scan.
    c. Discuss a technique for calibrating the rectilinear scanner which will result in standard optical densities on the photographic film.
    d. Discuss how the intensity control setting on the gamma camera changes the film density on the thyroid scintiphoto.
  2. Salivary gland images
    a. Given specific values of speed, line spacing, and maximum counts per minute, calculate the information density which will be obtained on a salivary gland scan examination performed on the rectilinear scanner.
    b. Discuss how the information density determined on such a salivary gland scan examination can be altered.
    c. Consider how change in information density will affect the appearance of both rectilinear scans and gamma camera scintiphotos of a salivary gland.

VI. Clinical Procedures - Neurological

A. Units of Instruction
  1. Brain images
    a. Review of anatomy, physiology, and pathology
    b. Radiopharmaceuticals
    c. Radiopharmaceutical dosage
    d. Rectilinear scanner techniques
    e. Gamma camera techniques
    f. Patient preparation
    g. Examination artifacts
  2. Brain hemodynamic studies
    a. Review of anatomy, physiology, and pathology
    b. Radiopharmaceuticals
    c. Radiopharmaceutical dosage
    d. Patient preparation
    e. Gamma camera techniques
    f. Data manipulation and analysis
    g. Examination artifacts
  3. Cisternographic images
    a. Review of anatomy, physiology, and pathology
    b. Radiopharmaceuticals
    c. Radiopharmaceutical dosage
    d. Patient preparation
    e. Recilinear scanner techniques
    f. Gamma camera techniques
    g. Examination artifacts

B. Case Studies
  1. Brain images
    a. Discuss the concept of target to nontarget activity on brain scans and scintiphotos.
    b. Consider how this relationship differs from other organs.
    c. Discuss two methods for establishing examination techniques for brain scans on the rectilinear scanner based upon the unique target to nontarget relationship seen on the brain scan.
    d. Consider how this target to nontarget ratio changes with respect to time.
    e. Discuss how nontarget activity can alter the appearance of the brain scintiphoto obtained on the gamma camera and develop an examination technique which will minimize this effect.
  2. Dynamic brain examinations
    a. Discuss how collimator sensitivity is an important consideration in developing an examination technique for dynamic brain studies.
    b. Consider the design of a theoretical collimator, and optimize its characteristics for performing dynamic brain studies.
  3. Cisternographic images
    a. Discuss how collimator resolution is important in developing an examination technique for cisternograms on the rectilinear scanner and on the gamma camera.
    b. Consider the design of a theoretical collimator and optimize its characteristics for performing cisternograms on the rectilinear scanner and on the gamma camera.
    c. Consider how straight bore and focusing collimators affect the appearance of the cisternogram examination on the rectilinear scanner and on the gamma camera.

VII. Clinical Procedures - Skeletal and Soft Tissue

A. Units of Instruction

1. Bone images
    - a. Review of anatomy, physiology, and pathology
    - b. Radiopharmaceuticals
    - c. Radiopharmaceutical dosage
    - d. Patient preparation
    - e. Rectilinear scanner techniques
    - f. Gamma camera techniques
    - g. Radiographic correlation
    - h. Examination artifacts
2. Tumor localization
    - a. Review of anatomy, physiology, and pathology
    - b. Radiopharmaceuticals
    - c. Radiopharmaceutical dosage
    - d. Rectilinear scanner techniques
    - e. Gamma camera techniques
    - f. Examination artifacts
3. Bone density studies
    - a. Review of anatomy, physiology, and pathology
    - b. Bone densitometer techniques
    - c. Data manipulation and analysis
    - d. Examination artifacts

B. Case Studies

1. Bone images
    - a. Consider and discuss response-alternatives to a patient's fear about having a bone scan examination performed on him.
    - b. Consider and discuss response-alternatives to a patient's fear about receiving radioactive material for a bone scan examination.
    - c. Consider and discuss response-alternatives to a patient's questions about the results of his bone scan examination.
    - d. Consider and discuss response-alternatives to a patient's questions about his medical history.
2. Tumor localization images
    - a. Discuss examination artifacts which may be attributed to the patient as well as how such artifacts might appear on the tumor localization scan or scintiphoto.
    - b. Discuss examination artifacts which may be attributed to the examination technique as well as how such artifacts might appear on the tumor localization scan or scintiphoto.
    - c. Discuss other sources of examination artifacts not related to the patient or to examination technique and how such artifacts may affect the appearance of the tumor localization scan or scintiphoto.

VIII. Clinical Procedures - Therapeutic Uses

A. Units of Instruction

1. Thyroid therapy
    - a. Review of anatomy, physiology, and pathology
    - b. Radiopharmaceuticals
    - c. Techniques of administration
2. Malignant hematological disorders
    - a. Review of anatomy, physiology, and pathology
    - b. Radiopharmaceuticals
    - c. Techniques of administration
3. Intracavitary
    - a. Review of anatomy, physiology, and pathology
    - b. Radiopharmaceuticals

B. Case Studies

1. Thyroid therapy
    - a. Perform radioisotope therapy dose calculations using formulas, tables, and charts.
    - b. Discuss formats for records of patient radioisotope therapy doses.
    - c. Consider how a therapeutic dose of radioisotope may vary with age of patient, weight of patient, isotope used, and disease or condition to be treated.
    - d. Discuss the design of a form to be placed in the patient chart which will alert the hospital staff as to special precautions to be taken with patients who contain therapeutic amounts of radioisotopes.

IX. Clinical Procedures - Competitive Binding Assays

A. Units of Instruction

1. Thyroxine, total and free
2. T3 and T4
3. TSH
4. Vitamin B12
5. Digoxin and digitoxin
6. Angiotensin I and II
7. Insulin
8. Hepatitis associated antigen
9. Gastrin
10. Folic acid
11. Total iron binding capacity
12. Human growth hormone
13. Other

B. Case Studies

1. B12, Gastrin, T3, and T4
    - a. Consider the effect of inaccurate pipetting techniques on serum B12, Gastrin, and T3 and T4 determinations.
2. Angiotensin I and II and insulin
    - a. Discuss the effects of incubation temperature on angiotensin I and II and insulin determinations.
    - b. Given sample sets of numerical test data, and the appropriate formulas, calculate angiotensin I and II and insulin determinations.
3. Digoxin
    - a. Discuss the effects of incubation time on digoxin determinations.
    - b. Given sample sets of numerical test data, and the appropriate formulas, calculate digoxin determinations.
4. B12 and folate
    - a. Given a sample set of numerical data, plot a standard curve to be used in calculating B12,and folate determinations.
    - b. Discuss the effects of an inaccurate standard curve on B12 and folate determinations.
    - c. Discuss the causes of an inaccurate standard curve.

Texts and References

Blahd. Nuclear Medicine

Deland and Wagner. 3-Volume Atlas of Nuclear Medicine

Maynard. Clinical Nuclear Medicine

Quimby. Safe Handling of Isotopes in Medical Practice

Quimby et al. Radioactive Nuclides in Medicine and Biology - Instrumentation

Silver. Radioactive Nuclides in Medicine and Biology - Medicine

Sodee and Early. Technology and Interpretation of Nuclear Medicine Procedures

Wagner. Principles of Nuclear Medicine

PERFORMANCE OBJECTIVES FOR CLINICAL NUCLEAR MEDICINE TECHNOLOGY II

I. CLINICAL PROCEDURES - CARDIOVASCULAR/PULMONARY

A. The student should be able to:

1. Locate the major segments of the lobes of the lungs given an anatomical model.
2. Identify three types of lung pathology which may result in a positive lung scan.
3. Identify the major arteries and veins of the heart given an anatomical model.
4. Calculate percent of remaining activity at specified intervals of time given the concentration of technetium labeled microspheres at T_0.
5. Define the term "information density."
6. Given speed, line spacing, and count rate, calculate information density.
7. Distinguish between parallel hole and focusing collimators.
8. Explain how detector sensitivity differs between ^{99m}Tc and ^{133}Xe.
9. Describe the importance of obtaining a recent X-ray of the chest when performing lung scans, cardiac blood pool, and ventilation examinations.
10. Identify two radiopharmaceuticals which may be used to obtain images of the heart.

II. CLINICAL PROCEDURES - GASTROINTESTINAL

A. The student should be able to:

1. Determine the concentration 24 hours before on Tuesday given the concentration of ^{131}I Rose Bengal as 200 uCi/ml on Wednesday.

II. CLINICAL PROCEDURES-GASTROINTESTINAL (continued)

2. Define the meaning of collimator resolution.
3. Explain what changes in instrument technique would be required when performing liver scans with ^{131}I Rose Bengal, and ^{99m}Tc-sulfur colloid on the gamma camera.
4. Describe the relationship between the number of counts collected and the oscilloscope intensity settings on the gamma camera.
5. Given the information density, line spacing, and count rate, calculate speed on the rectilinear scanner.
6. Describe how the appearance of the lateral projection of the liver is affected by whether the projection is obtained from above or below the imaging table.
7. Identify 5 parameters which affect image quality on the gamma camera.
8. Identify 2 types of pathology which may result in a positive pancreas scan.
9. Specify the volume of ^{75}Selenomethionine to be drawn up for a pancreas scan if the dose to be administered is 200 uCi, and concentration of the radiopharmaceutical is 275 uCi/ml.
10. If a ^{99m}Tc liver scan is combined with a ^{75}Se pancreas scan, special care must be taken when peaking the analyzer. Explain.

III CLINICAL PROCEDURES-RENAL

A. The student should be able to:

1. Describe the difference between glomerular and tubular filtration.
2. Explain why renal procedures are especially useful in the evaluation of kidney transplant patients.
3. Decide if high energy collimators may be used with low energy isotopes. Is the reverse true? Explain using the ^{99m}Tc and ^{131}I renal scan and renogram as an example.
4. Describe the relationship between resolution and sensitivity.

III. CLINICAL PROCEDURES-RENAL (continued)

5. Define the term "functional image."
6. Explain why isotopic renal studies are especially valuable in patients which have allergies to iodine.
7. Identify three phases or components of the normal renogram curve.
8. When performing renograms with a dual probe uptake system, what is the most common cause of an unsatisfactory examination?
9. Describe the term "flat field collimator."
10. Describe the term "chlormerodrin accumulation test."

IV. CLINICAL PROCEDURES-HEMATOLOGICAL

A. The student should be able to:

1. List two common uses of the spleen scan examination.
2. Describe the splenic sequestration study.
3. Identify and describe the view which is most commonly used to separate the spleen from the liver on a spleen scan.
4. Define the term "splenomegaly."
5. When labeling red blood cells with ^{51}Cr Sodium Chromate for spleen scanning, explain why the incubation temperature is critical.

V. CLINICAL PROCEDURES-ENDOCRINE/EXOCRINE

A. The student should be able to:

1. Describe the difference between thyrotoxicosis and myxedema.
2. Identify three functions of the thyroid gland.
3. Describe the PBI determination.
4. Describe the T_3 determination.
5. Describe the difference between pin hole and parallel hole collimators.

V. CLINICAL PROCEDURES - ENDOCRINE/EXOCRINE (continued)

6. Describe the circumstances under which the radioactive technetium thyroid scan is often substituted for the radioactive iodine scan.

7. Define the term "Hashimoto's Disease."

8. Describe the basic changes in instrument technique between the technetium and iodine thyroid scan performed on the rectilinear scanner.

9. State what the information density will be if the scanner is operated at 180 cm/min with line spacing of 1.0mm given that the maximum count rate over the salivary glands is 10,300 cpm.

10. Determine, if an iodine capsule contains 25 uCi of ^{131}I on Monday at 11:00 A.M., how much ^{131}I will be present on Wednesday at the same time.

VI. CLINICAL PROCEDURES - NEUROLOGICAL

A. The student should be able to:

1. Describe the difference between a mengioma and a hematoma.

2. Define CVA and describe its appearance with respect to the passage of time on the brain scan.

3. Define target to non target ratio.

4. Explain how the brain scan examination differs from most other organ images in terms of the target to non target relationship.

5. Define the concept of contrast enhancement, and explain how it can alter the appearance of the rectilinear brain scan.

6. Explain why potassium perchlorate or sodium perchlorate is often administered to the patient prior to the brain scan examination.

7. If atropine is administered prior to performing a brain scan examination, explain its function and identify the view for which it is most useful.

8. Identify the gamma camera collimator often used for close up views of the brain, and identify the view for which this collimator is most often used.

VI. CLINICAL PROCEDURES-NEUROLOGICAL (continued)

9. Identify the vessels which can be seen most readily on the normal anterior cerebral flow study.

10. Identify two undesirable properties of ^{131}I RISA as a radiopharmaceutical agent used for cisternography.

VII. CLINICAL PROCEDURES-SKELETAL AND SOFT TISSUE

A. The student should be able to:

1. Describe the difference between osteoblasts and osteoclasts.

2. Identify a characteristic of ^{18}F which makes it unique among most bone scanning radiopharmaceuticals.

3. Identify the patient preparation received prior to a bone scan examination with ^{85}Sr.

4. Describe the similarities and differences between ^{85}Sr and ^{87m}Sr.

5. Identify the isotope that can be used for bone mineral or bone density examinations.

6. Given that at the time of calibration, there are 3 mCi/ml of ^{67}Ga, determine how much ^{67}Ga must be drawn up for a tumor localization study 8 days later. Assume dose of 2.0 mCi.

7. Explain why the rectilinear scanner is inherently more sensitive to ^{18}F than is the gamma camera.

8. Identify areas where radiopharmaceuticals may be deposited on the normal bone marrow examination.

9. Explain why the maximum permissible dose for ^{85}Sr bone scans is so much smaller than the dose for a ^{87m}Sr bone scan.

10. Given that colon activity is a concern on ^{85}Sr bone scans, identify areas of similar concern on ^{18}F bone scans.

VIII. CLINICAL PROCEDURES-THERAPEUTIC USES

A. The student should be able to:

1. Determine how many millicuries/ml will be present the following Monday, given that the ^{131}I concentration on Monday is 100 mCi/ml.
2. Determine on what day the patient may be discharged if the isotope manual states that a patient may be discharged only after the activity reaches 1.0 millicurie, given the administration of 15 mCi of ^{131}I for thyroid cancer therapy. Assume no biological decay.
3. Identify two radioactive colloid suspensions which may be used for intracavitary therapy.
4. Identify the primary type of radiation associated with radioactive colloids used for therapy.
5. Identify two therapeutic uses of ^{90}Sr.

IX. CLINICAL PROCEDURES-COMPETETIVE BINDING ASSAYS

A. The student should be able to:

1. Describe three uses of a centrifuge.
2. Define the term "counterbalancing solution" and explain its importance.
3. Identify the material used to coat iron bars used with magnetic stirrers and explain why such coating material is used.
4. Define the term "USP."
5. Define the term "rest point" of a balance.
6. Describe the process of zeroing a balance.
7. Describe the difference between mass and weight.
8. Define readability of a balance.
9. Define the term "arresting a balance."
10. Identify three rules for maintaining the accuracy and reproducibility of a balance.
11. Identify four common sources of error in weighing.

IX. CLINICAL PROCEDURES-COMPETETIVE BINDING ASSAYS (continued)

12. Describe the basic differences between the single pan, double pan, torsion, and triple beam balances.

13. Define the terms "liter," "milliliter," and "cubic centimeter."

14. Define the term "titration."

15. Define the terms "standard solution," "equivalence point," and "end point."

16. Define the term "meniscus" and describe how it should be read.

17. Describe the term "parallax error."

18. Describe the difference between a volumetric or transfer pipette, and a measuring pipette.

19. Define the term "aliquot."

20. Describe the difference between pipettes and burettes.

21. Define the terms "pH," "acids," and "bases."

22. Define the term "buffer solution."

23. When using a pH meter, the electrodes should not be allowed to touch the sides of the beaker. Explain.

24. Describe the difference between gravity and vacuum filtration.

25. Describe the processes of decantation, washing, and transfer during the process of filtration.

26. Define the term "activated charcoal."

27. Identify the isotope most commonly used to perform T_4 determinations.

28. Explain how the T_4 value is related to thyroid function.

29. Identify two conditions which will cause the T_4 value to rise.

30. Identify two conditions which will cause the T_4 value to decrease.

31. If a patient is pregnant, will her T_3 value be raised or lowered. Explain.

IX. CLINICAL PROCEDURES-COMPETETIVE BINDING ASSAYS (continued)

32. If a patient is undergoing Androgen therapy, will her T_3 value be raised or lowered. Explain.

33. Identify two isotopes commonly used to perform T_3 determinations.

34. Identify two isotopes commonly used to perform Angiotensin I and II determinations.

35. Identify the isotope of Iodine commonly used to perform serum insulin determinations.

36. Describe how human growth hormone may be affected by the glucose level in the blood.

37. Explain how the TSH value is related to thyroid function.

38. Identify the isotope used in the determination of serum insulin.

39. Identify the isotope used in the determination of serum gastrin.

40. Identify the isotope used in the determination of serum folic acid.

TECHNICAL REPORTING

Hours Required

Class, 3

Course Description

TECHNICAL REPORTING is an extension of COMMUNICATIONS SKILLS and is designed to add breadth to the student's reading and writing skills. In addition, emphasis is placed on research techniques and illustrations since these are often essential and neglected elements in technical reporting skills development. The first three weeks of the semester include sections on reading and analyzing technical reports to provide the student with models for his or her endeavors. The course should include a student project which requires collection, analysis, illustration, and writing of a technical report. The development of the report should parallel the course work so that the report is written during the 15 weeks of the semester. Emphasis should then be placed on the student's assessing and correcting his own errors in grammar, spelling, and punctuation.

Major Divisions		Semester Class Hours
I.	Reading Technical Reports: Separating Fact from Opinion	6
II.	Review of Scope and Functions of Technical Reports	3
III.	Research Techniques	9
IV.	Illustrations	7
V.	Writing a Report	15
VI.	Oral Presentations and Corresponding Illustrations	5
	Total	45

I. Reading Technical Reports: Separating Fact from Opinion

A. Units of Instruction

1. Defining the purpose of a communication
2. Recognizing propaganda by selection of words and tone
3. Selection and omission of facts
4. Bias in numbers, statistics, charts, and graphs
5. Checking assumptions

II. Review of Scope and Function of Technical Reports

A. Units of Instruction

1. Types of scientific technical reports
    a. The abstract
    b. Process explanation
    c. Case history
    d. Evaluations
2. The scientific method, a review
3. Purpose, audience, and scope of technical communications
4. Function of hypothesis and thesis in planning a report

III. Research Techniques

A. Units of Instruction

1. Review of research materials for nuclear medical problems
2. Collecting data from secondary sources
3. Analyzing data from secondary sources
    a. Checking logic
    b. Checking statistics
    c. Testing assumptions and conclusions
4. Collecting original data
    a. Writing a questionnaire, lab data sheet, or other instrument for data collection
    b. Importance of accurate recording keeping
    c. Assessing accuracy of data
        i. Determining percent of error
        ii. Assessing the human factor
5. Analyzing original data
    a. Checking accuracy
    b. Advantages and disadvantages of elementary analytical techniques

IV. Illustrating Reports

A. Units of Instruction

1. Selection of appropriate illustrations
    a. Availability
    b. Cost of preparation
    c. Maximum brevity and clarity of presentation
    d. Correlating illustrations with written material
2. Diagrams
    a. Electrical diagrams and symbols
    b. Process flow diagrams
    c. Instrumentation diagrams
    d. Bar charts, pie diagrams, and similar representations of data

3. Graphical presentations
    a. Types of graph paper
    b. Choice of scale
    c. Points and lines
    d. Use of data from graphs
4. Use of photographs

V. Writing a Report

A. Units of Instruction

1. Organizing the report
    a. The bibliography
    b. Notes and outlines
    c. The rough draft
2. Providing unity through paragraphing
    a. The sentence
    b. Importance of the topic sentence to a paragraph
    c. Checking the flow of ideas from paragraph to paragraph
    d. Using the outline to check logic
    e. The importance of a thesis statement
    f. Writing an introduction and a conclusion
3. Checking on the details of presentation
    a. Checking for common errors of grammar
        i. Sentence fragment
        ii. Sentence splices
        iii. Faulty reference
    b. Correcting spelling errors
    c. Footnoting
    d. Quoting
    e. Integrating illustrations and written material
    f. Checking accuracy of displays of data

V. Oral Presentation and Corresponding Illustrations

A. Units of Instruction

1. Difference in organization of oral presentations and written reports
2. Formal and informal reports
3. Organization of notes for informal reports
4. Use of transparencies, slides, charts, or chalkboard for illustrations
    a. Advantages and disadvantages of each technique
    b. Common problems in illustrations
5. Proper use of voice
6. Avoiding common error
7. Importance of the introduction

Texts and References

Crouch and Zetler. Guide to Technical Writing.

Harwell. Technical Communications.

Hays. Principles of Technical Writing.

Luzadder. Graphics for Engineers.

Marder. The Craft of Technical Writing.

Menzel et al. Writing a Technical Paper.

Sherman. Modern Technical Writing.

Sigband. Effective Report Writing.

Souther. Technical Report Writing.

Tracy and Jennings. Handbook for Technical Writers.

Zetler and Couch. Successful Communication in Science and Industry.

Handbooks

Buckley and McAvory. American College Handbook of English Fundamentals.

Fowler. A Dictionary of Modern English Usage.

Gerber. The Writer's Resource Book.

Nicholson. A Dictionary of American-English Usage.

Perrin and Smith. Handbook of Current English.

Warriner and others. English Grammar and Composition: A Complete Handbook.

SUMMER

Clinical Practicum III

SUMMER

CLINICAL PRACTICUM III

Hours Required

Hospital, 40

Course Description

CLINICAL PRACTICUMS I AND II are designed to introduce students to the fundamental procedures and techniques performed in the nuclear medicine unit. Through observation during the first practicum and supervised participation in the second, the student has been prepared to begin CLINICAL PRACTICUM III.

CLINICAL PRACTICUM III is designed to round out the student's base of experience in performing all nuclear medicine examinations while increasing his skills and self-confidence. This is accomplished through the student's full-time presence in the nuclear medicine facility.

A majority of the topic-related activities are not described as supervised; however, it is expected that instructor guidance will continue at a close level throughout the early phases of this practicum becoming less structured as the student increases his level of proficiency in performing the activities described. Although the major divisions of this practicum are outlined in a specific sequence, it is doubtful whether the hospital environment will allow patient material to be presented in this sequence. It is essential therefore, that a check list be developed which will enable the student, together with the instructor, to monitor the student's exposure to each type of examination procedure and topic related activity. Use of such a check list will help to insure that the student gains adequate experience in all areas of nuclear medicine technology.

Students, upon completion of this practicum, should be skilled in performing all routine and nonroutine nuclear medicine examinations and laboratory procedures. He should also possess a demonstrated understanding of the theory and concepts underlying such procedures. In addition to procedural technique, the student will have developed the maturity and self-confidence essential to the efficient and effective operation of the nuclear medical team.

This practicum has been scheduled for the summer after the second year of coursework.

Major Divisions		Semester Class Hours
I.	Cardiovascular/Pulmonary Examinations	40
II.	Gastrointestinal Examinations	40
III.	Renal Examinations	40
IV.	Hematological Examinations	40
V.	Endocrine/Exocrine Examinations	40
VI.	Neurological Examinations	40
VII.	Skeletal and Soft Tissue Examinations	40
VIII.	Therapeutic Procedures	25
IX.	Competitive Binding Assays and Other Determinations	121
X.	Nursing Procedures	25
XI.	Administrative Procedures	29
	Total	480

I. Cardiovascular/Pulmonary Examinations

II. Gastrointestinal Examinations

III. Renal Examinations

IV. Hematological Examinations

V. Endocrine/Exocrine Examinations

VI. Neurological Examinations

VII. Skeletal and Soft Tissue Examinations

A. Obtain positive identification of patients scheduled for nuclear medicine examinations.

B. Assess the patient's understanding of the examination to be performed, and proceed with an appropriate explanation of the procedure.

C. Answer questions patients may have concerning the examination procedure.

D. Where appropriate, establish that the patient has undergone necessary pre-examination preparation.

E. Determine whether the patient has undergone any other examination or procedure which would interfere with the nuclear medical examination.

F. Calculate and draw up radiopharmaceutical dose for the examination procedure. Have results verified.

G. Organize injection tray and dispose of waste materials after the dose has been administered.

H. Modify routine positioning techniques as required for patients with special problems.

I. After the patient has been positioned, calculate and set parameters of the instrumentation.

J. Modify parameters of the examination technique as necessitated by the quality control review of the examination results.

K. Discuss correlation of examination results with relevant data from the patient chart and examination requisition.

L. Organize the examination record for physician interpretation.

M. Discharge the patient from the nuclear medicine facility.

VIII. Therapeutic Procedures

A. Obtain positive identification of patients scheduled for therapeutic procedures.

B. Assess the patient's understanding of therapy to be administered, and proceed with an appropriate explanation of the procedure.

C. Answer questions patients may have concerning the therapy administration.

D. Where appropriate, establish that the patient has undergone necessary pre-therapy procedures.

E. Determine whether the patient has undergone any other examination or procedure which would interfere with the therapy administration.

F. Calculate and prepare radiopharmaceutical dose for the therapeutic procedure. Have results verified.

G. Organize administration tray, and dispose of waste after the radiopharmaceutical has been administered.

H. Complete records of the therapy administration.

I. Ensure that patient precautions are posted upon discharge of the patient from the nuclear medicine facility.

IX. Competitive Binding Assays and Other Determinations.

A. Enter all required data in laboratory logs including patient sample identification data, control standard data, test results, etc.

B. Using appropriate laboratory equipment and techniques prepare standards used in performing competitive binding assays and other determinations.

C. Calculate and plot standard curves.

D. Using appropriate laboratory equipment and techniques prepare patient samples for competitive binding assays and other determinations.

E. Using liquid scintillation or other counting systems, count samples and standards.

F. Calculate results of competitive binding assays and other determinations. Verify results.

G. Modify procedural techniques as necessitated by quality control review of test results.

H. Dispose of radioactive waste materials associated with laboratory tests.

I. Organize patient record for physician report.

X. Nursing Procedures

A. Obtain blood pressure, temperature, and respiration on simulated patients.

B. Operate suction and oxygen apparatus with simulated patients.

C. Move simulated patients requiring special techniques for nuclear medicine examinations.

D. Supervise decontamination of simulated patients who have become contaminated with radioactive materials.

E. Participate in the organization of plans for dealing with emergencies including nuclear medicine patient emergencies, civil emergencies, and national emergencies.

F. Perform supervision of patient handling during simulated emergency situations.

G. Discuss conversational ethics between the patient and the technician.

XI. Administrative Procedures

A. Discuss AEC licensing regulations and impact of other regulatery agencies upon the hospital, e.g. FDA, State Board of Health, Joint Commission on Accreditation of Hospitals, etc.

B. Develop budgets and establish mechanisms for accessing performance of the nuclear medicine facility.

C. Discuss cost accounting and examination pricing for nuclear medicine examinations and laboratory procedures.

D. Discuss hospital policy regarding personnel and salary administration.

E. Discuss the legal issues which affect the activities of the nuclear medicine facility.

F. Assess the role of the Chief Nuclear Medicine Technologist.

G. Discuss the team concept in nuclear medicine.

Texts and References

See Clinical Nuclear Medicine Technology I

Additional References

NMT Department's Procedure Manual

Manufacturers' Instruction Manuals for NMT equipment

LABORATORY FACILITIES, EQUIPMENT, AND COSTS

General Planning of Facilities

Appropriate laboratory facilities for an NMT program are a crucial component for the program's success. Facilities already in existence can be used for a number of science courses which include Anatomy, Physiology, and Pathology I & II, Chemistry for the Health Services, and Nuclear Instrumentation I. Special facilities and equipment are required for second-year courses such as Fundamentals of Radiochemistry and Radiopharmaceuticals, and Nuclear Instrumentation II. If adequate facilities are available for students, it would be advantageous to conduct related academic courses in the laboratory for demonstration purposes. If the laboratory is designed for multiple sessions of small numbers of students, the lecture hour may be conducted in adjacent classrooms.

The Laboratory for Radiochemistry and Radiopharmaceuticals and for Nuclear Instrumentation I and II

A program training only a small number of NMT students may offer laboratory sessions for Radiochemistry and Radiopharmaceuticals and Nuclear Instrumentation II at nearby hospitals if it is difficult to establish a laboratory on campus. Community colleges and technical institutes graduating twenty students per year should plan to establish a basic nuclear science laboratory when the program is implemented, calling upon hospital facilities for student training on more expensive items of equipment such as gamma cameras, rectilinear scanners, and liquid scintillation counters.

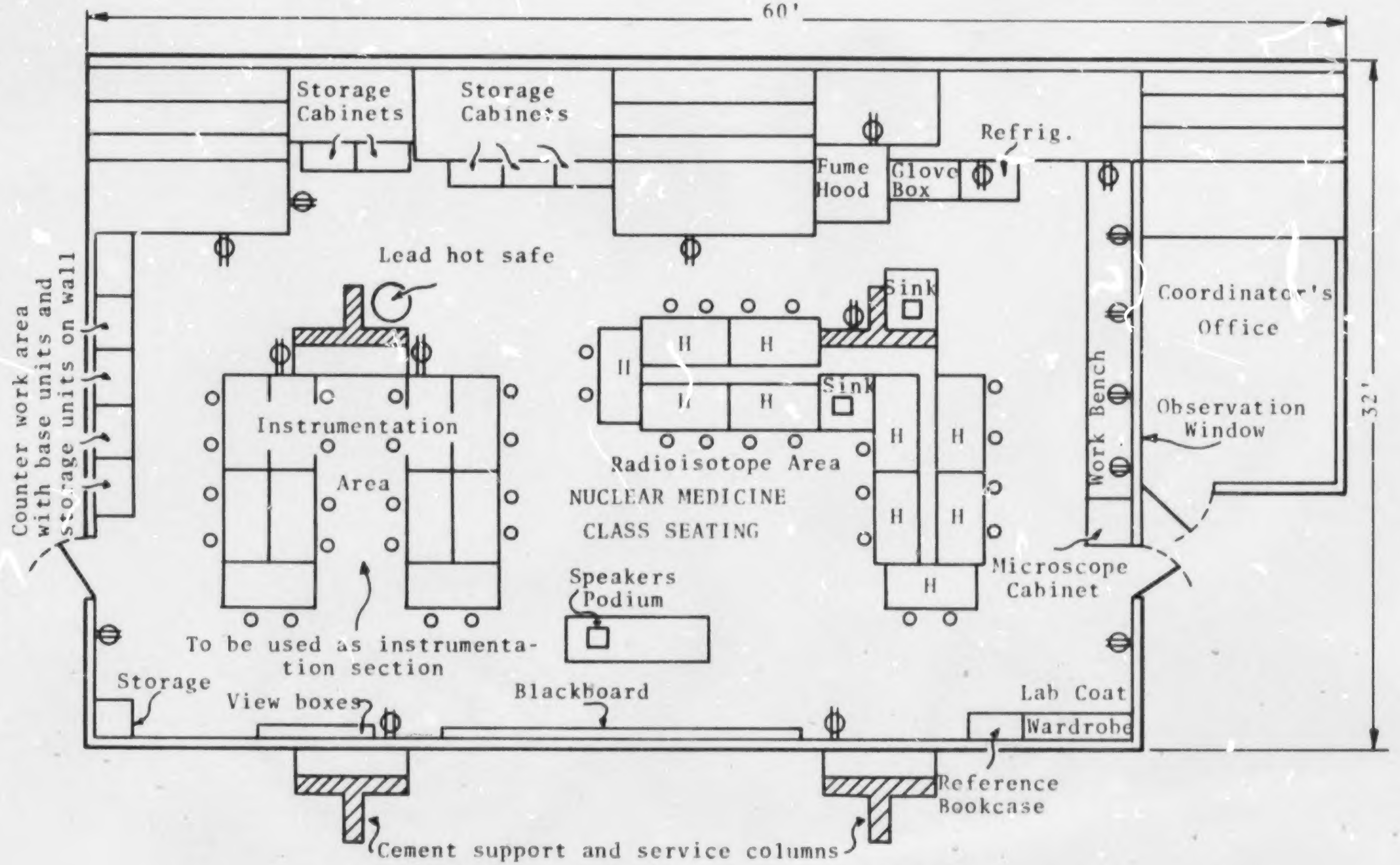
Laboratory sessions using hospital-owned equipment may have to be scheduled for evening hours when the hospital facilities are not being used for patients. More than one hospital may be necessary to ensure that no more than two students are working simultaneously with one piece of instrumentation. Arrangements should be made with hospital staff for compensation to assist in conducting these evening laboratory sessions.

Space required for teaching both Nuclear Instrumentation I and II and Fundamentals of Radiochemistry and Radiopharmaceuticals ranges from forty to eighty square feet per student. Figure 1 illustrates a laboratory with accommodation for twenty students.

The four major areas in Figure 1 are: the instrumentation area, radioisotope area, lecture area, and coordinator's office. The instrumentation area contains ten set-ups accommodating twenty students to conduct nuclear

FIGURE 1

COMBINATION CLASSROOM/LABORATORY FOR NMT


60'
32'
Storage Cabinets
Storage Cabinets
Fume Hood
Glove Box
Refrig.
Lead hot safe
Sink
Sink
H
Coordinator's Office
Observation Window
Work Bench
Counter work area with base units and storage units on wall
Instrumentation Area
Radioisotope Area
NUCLEAR MEDICINE CLASS SEATING
Microscope Cabinet
Speakers Podium
To be used as instrumentation section
Storage
View boxes
Blackboard
Lab Coat Wardrobe
Reference Bookcase
Cement support and service columns

H = Chemistry tables with air, vac, gas, water, available to all students

Radioisotope Area = To be used for all chemistry, RIA, in-vitro, etc. experiments

Work Bench = (pH meters, microscopes, etc.)

instrumentation experiments. The radioisotope area is equipped for an equal number of students to perform experiments in radiochemistry and radiopharmacy. Each station has vacuum, water, gas, and compressed air lines. A demonstration/lecture area is conveniently located in the center of the laboratory. The coordonator's office is situated so that he can easily oversee laboratory activities.

Radiation safety considerations are important in the design and operation of any laboratory using radionuclides. The area should be posted and film badges or other personnel monitoring devices should be required. Provision must be made for storage space outside the laboratory so that coats, books, and other personal belongings are not brought into the laboratory. A space inside (lower right of Figure 1) is designed for laboratory coats and film badges for each student to wear during the session and to be retained within the lab. Safety requires that no eating, drinking, or smoking is permitted in the laboratory.

Storage of radionuclides is shown in two areas, the lead hot safe and the refrigerator/freezer. It should be noted that the hot safe is additionally shielded from the instrumentation area by a cement column. The lead-lined refrigerator/freezer is used to store radioimmunoassay kits, blood and serum samples, and certain chemicals.

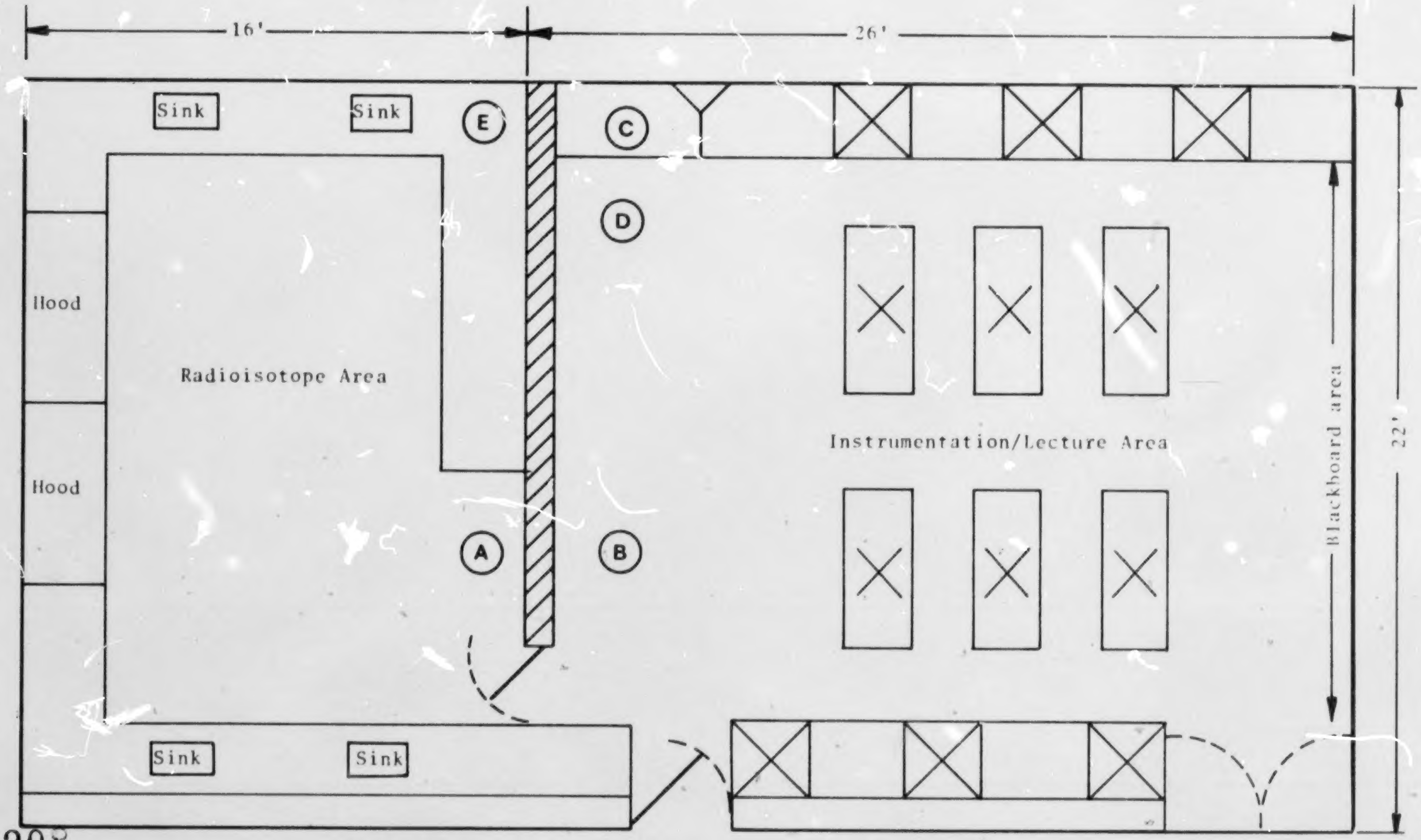
Radionuclides should be handled in a manner that minimizes exposure. This should be done by working quickly using lead shield, tongs, tweezers, and by wearing gloves. Liquid samples should be transported in plastic trays to contain spills. Floor and counter surfaces should be made of a nonporous material to facilitate decontamination if uncontained spills do occur.

Safe areas for preparing volatile radionuclides, a fume hood, and glove box are shown in the upper right of Figure 1. The airflow velocity into the hood should be at least 100 feet per minute. The exhaust system should not be connected to other hoods. The glove box will be required only when 100 mCi or more is handled, when there is a risk of serious spills, or when dry and dusty radionuclides are handled.

Safe disposal of wet and dry radionuclide wastes must be provided for. A "hot" sink is used for liquid wastes. The necessary amount of water for diluting a given quantity of radionuclides can be calculated (Shapiro, Radiation Protection, 1974). A covered container for radioactive dry waste is also necessary. The waste is generally accumulated for shipment to a radioactive waste disposal site.

A lecture/demonstration area for twelve to eighteen students with a laboratory area for six to eight students is shown in Figure 2. In this arrangement two or three lab sessions must be conducted to accommodate all the students.

FIGURE [illegible]
RADIATION SCIENCE LABORATORY


16'
26'
22'
Sink
Sink
E
C
D
Hood
Radioisotope Area
Hood
A
B
Instrumentation/Lecture Area
Blackboard area
Sink
Sink

A = Lab refrigerator - Radionuclide Storage Area w/lock
B = Single Probe Rectilinear Scanner
C = Multichannel Analyzer System
D = Well Counter Probe System
E = Dose Calibrator

A small teaching laboratory can be designed for six students. The unique features of this laboratory are the rectilinear scanner and dark room. By using a scanner in a laboratory setting, an instructor can demonstrate many of the principles for obtaining a good image using radionuclide-filled phantoms. Since the main output of a scanner is a photographic film, a darkroom is necessary. Either manual or automatic film development can be used. The darkroom may be shared with a radiologic technology program.

Regulations for the Use of Radioactive Substances

When planning laboratory facilities, federal and state controls for the use of radioisotopes must be taken into consideration. A federal license must be obtained. The application form AEC-313 is available through the U. S. Atomic Energy Commission, Directorate of Licensing, Washington, D. C. 20545. The application will request information about types of materials being used, the training of individuals responsible for the materials, and the types of equipment. (A copy of the Application for By-product Material License, Form AEC-313 is included in Appendix F.)

The Federal Register Title 10, Part 20, Standards of Protection Against Radiation is a necessary reference document which can be obtained from the local government printing office or the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402. It contains information about maximum permitted radioactive doses, the proper identification of radiation areas, personnel monitoring devices, and the maximum concentration at which various radioactive waste gases and liquids can be discharged into the environment.

State licensing is generally administered by the State Department of Public Health. Local authorities should be contacted for information regarding local ordinances about radioactive waste disposal. The radiation protection officers at the affiliated hospitals are a good resource for further information about radioactive safety requirements.

As stated in the National Council on Radiation Protection and Measurements (NCRP) Report #32, Radiation Protection in Educational Institutions, NCRP Publications, P. O. Box 4867, Washington, D. C., the radiation protection program is primarily the responsibility of the instructor who supervises the use of the radiation sources. Therefore, the instructor should share the responsibility for laboratory layout.

Lighting and Electrical Services

Adequate lighting is provided by 50-foot candles at the top of working surfaces. There should be at least one 30-ampere 115 115 VAC circuit per working station. It is essential that all nuclear medicine equipment be on separate circuits isolated from electrical interference of centrifuges, typewriters, calculators, and so forth.

Equipment

Equipment required for Fundamentals of Radiochemistry and Radiopharmaceuticals and its cost is listed in Table I. A locked storage area for consumable items such as chemicals and syringes is needed in addition to the lead storage container or safe. Microscopes, balances, pH meters, and centrifuges are necessary equipment. At least one liquid chromatography apparatus, hot plate and stirrer, and IR heat lamp and stand are required. Standard laboratory glassware completes the list.

Equipment and supplies required for Nuclear Instrumentation I and II are listed in Table II. The first nine items are related to radiation monitoring and protection. The multi-channel analyzer for demonstration purposes can be eliminated if required by financial considerations.

Equipment costs for Nuclear Instrumentation II experiments are not given because these items are usually used in the hospital due to their high cost. They include a rectilinear scanner, gamma camera, and liquid scintillation counter. A few schools do have some of these instruments available for teaching purposes only, but most teaching programs use hospital instruments during hours when they are not scheduled for patient use.

Summary of Costs

Construction costs for an unfurnished laboratory in 1974 are estimated at $[illegible] per square foot. Renovation of existing space may be less expensive. Stationary furniture such as lab benches, cabinets, and hoods with utilities connected are estimated to cost an additional $40 per square foot. The tables on pages 199-200 indicate costs for completing a laboratory to teach Nuclear Instrumentation I and Fundamentals of Radiochemistry and Radiopharmacy to a 24-student class based on two laboratory sessions each having twelve students sharing six work stations.

Table I

FUNDAMENTALS OF RADIATION CHEMISTRY AND RADIOPHARMACEUTICALS LABORATORY EQUIPMENT

Quantity	Item	Total Estimated Cost January 1, 1974
1	Lead storage container or safe	$ 720
1	Protective lead shield with window	480
1	Lead lined refrigerator	600
1	Radionuclide dry waste contianer	216
6	Grip tongs 36"	144
3	Binocular microscope X 120 with Polaroid camera attachment	3,600
3	Centrifuge	900
6	Microbalance	1,440
3	Ph meter	1,440
1	Liquid chromatography apparatus	144
6	Hot plates and stirrers	720
6	Heat lamps and stands	120
1	Glove box or hood	1,120
6 sets	Standard laboratory glassware including pipets, flasks, beakers, test tubes, etc.	720
	TOTAL	$12,424

Table II

NUCLEAR INSTRUMENTATION I - LABORATORY EQUIPMENT

Quantity	Item	Total Estimated Cost January 1, 1974
1 set	Radiation signs, labels and tape	$ 20
250/yr.	Film badges and readout service	250
1	Photodensitometer	180
1	Pocket dosimeter (200 mR)	45
1	Dosimeter charger and case	65
1	Dosimeter calibrator	38
1	Survey meter (β & γ)	400
1	Geiger-Mueller counter	1,000
1	Ionization chamber	500
1	Dose calibrator	2,500
1 set	Calibrated radionuclide sources	500
1 set	Uncalibrated Cs - 137 sources	15
4	Lab counting modules, including scintillation detectors, amplifier, single-channel pulse height analyzer, timer, and counter	20,000
1	Multi-channel analyzer	8,000
	TOTAL	$ 33,513

Construction Costs and Stationary Furniture	
1,000 square feet @ $90 per square foot	$ 90,000
Laboratory Equipment	
Fundamentals of Radiochemistry and Radiopharmaceuticals	12,424
Nuclear Instrumentation I	33,513
Audiovisual Teaching Aids	1,400
Expendable materials, replacement parts, supplies and maintenance	3,000
TOTAL	$140,337

Although most equipment must be purchased or leased by the school, there are sources of free or inexpensive equipment. For example, equipment no longer needed by Veterans' Administration hospitals or other government facilities may be available; the State Director of Vocational and Technical Education can provide specific information about surplus property in his area. Hospitals or NMT equipment manufacturers are also a possible source of used equipment. The NMT program Advisory Committee members representing hospitals and industry can assist in locating such equipment and evaluating its usefulness in the school NMT laboratory.

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APPENDICES

APPENDIX A

AMA Essentials of an Accredited Educational Program in Nuclear Medicine Technology

American Medical Association Council on Medical Education

Essentials of an Accredited Educational Program in Nuclear Medicine Technology

July, 1969

PREAMBLE

The organization primarily concerned with the maintenance of acceptable standards for educational programs for nuclear medicine technologists and technicians is the Council on Medical Education of the American Medical Association. The American College of Radiology, the Society of Nuclear Medicine, the American Society of Clinical Pathologists, the American Society of Medical Technologists, the American Society of Radiologic Technologists, and the Society of Nuclear Medical Technologists have obvious interest and concern in such training. To organize their concerns and provide an orderly mechanism for preparation of recommendations to the Council on Medical Education, a single Board of Schools of Nuclear Medicine Technology shall be concerned with the evaluation and survey of educational programs for Nuclear Medicine Technologists and Technicians, the maintenance of high standards of education, and the development of new teaching programs.

The Board of Schools of Nuclear Medicine Technology shall consist of two representatives each from the American College of Radiology, the American Society of Clinical Pathologists, and the Society of Nuclear Medicine, and two representatives each, registered in nuclear medicine technology, from the American Society of Radiologic Technologists, the American Society of Medical Technologists, and the Society of Nuclear Medical Technologists.

The Board of Schools shall serve as the reviewing body for all educational programs for Nuclear Medicine Technology and make recommendations to the Council on Medical Education of the American Medical Association concerning approval status.

Nuclear Medicine Technologists and Technicians are trained in these programs to work under the direction of physicians qualified in the clinical use of radionuclides, and not to work as independent practitioners.

I. Organization

A. Acceptable schools for training in nuclear medicine technology may be conducted in approved medical schools, accredited colleges or universities, accredited general hospitals or other acceptable laboratories suitably organized in accordance with present educational standards. Facilities providing clinical services in nuclear medicine must be maintained, and must provide an adequate volume and variety of procedures in relation to student enrollment. Under special circumstances, programs may be developed in specialty hospitals, laboratories, or in general hospitals where experience may not be possible in the full range of radionuclides. In such cases, the institution may arrange for affiliation with some other facility to provide training and experience in desired procedures with the approval of the Board of Schools of Nuclear Medicine Technology.

B. Affiliation with an accredited college, community college, university, or medical school is desirable but not essential. When such an affiliation exists, an advisory committee should be established including representatives from the sponsoring institution and from the department of the college, university, or medical school which participates in the training program.

C. All training of technologists and technicians shall be under competent medical supervision.

D. Resources for continued operation of the school should be assured through regular budget, gifts, or endowments. A monthly stipend to the student may be permitted.

II. Administration

A. The nuclear medicine faculty shall comply with federal, state, and hospital regulations for safety procedures. Adequate space, light, and modern equipment should be provided in the training area.

B. A library containing up-to-date references, texts, and scientific periodicals pertaining to nuclear medicine technology should be readily accessible to students.

C. Satisfactory records must be kept for all work accomplished in the department.

D. Transcripts of college credits and other credentials must be available. Records must be kept of each student's attendance and grades, as well as the number and types of technological procedures performed.

E. A current outline of the curriculum and the rotation of assignments must be available in the office of the program director.

F. Approval of a program may be withdrawn if no students are enrolled for a period of two consecutive years.

G. Institutions sponsoring programs for nuclear medicine technology should submit an annual report to the Council on Medical Education and to the Board of Schools of Nuclear Medicine Technology.

H. Periodic resurvey will be conducted by the Board of Schools of Nuclear Medicine Technology in collaboration with the Council on Medical Education. If the physician director in charge of the training program or the curriculum is changed, the Council shall be notified, and re-evaluation may be required.

III. Faculty

A. The program must have a competent and adequate teaching staff. The director must be a physician qualified in the clinical use of radionuclides. He must be eligible for certification by a medical specialty examining board recognized by the American Medical Association, or have qualifications acceptable to the Council on Medical Education. He shall take part in and be responsible for the actual conduct of the training program and shall be in daily attendance for sufficient time to supervise properly the work and teaching in the department.

B. The teaching staff should include qualified instructors in radiation physics and radiation biology adequate for both group and individual instruction. It should also include at least one instructor who is a registered nuclear medicine technologist and who is actively engaged in nuclear medicine technology.

IV. Admission Requirements

Applicants must be at least eighteen years of age at the time they reach the training period when they will be working with radionuclides. Candidates for admission must satisfy one of the following minimal requirements:

A. For Baccalaureate Degree Program; Technologists: Registered as a Medical Technologist, M.T. (ASCP); Radiologic Technologist, R.T. (ARRT); or Registered Nurse, R.N.; and have earned at least three years (90 semester hours) of college credit from an accredited college, university, or medical school, including credit acceptable toward a major in the biological or physical sciences.

B. For Associate Degree Programs; Technicians: Applicants must have successfully completed four years of high school or have passed a standard equivalency test for admission to a college. Successful completion of two years study, including the twelve month training program, may qualify the individual for an associate degree. For those who have successfully completed one year of college, including at least three credit hours in chemistry and mathematics, the twelve month training program may qualify the individual for an associate degree.

C. Those registered as M.T. (ASCP); R.T. (ARRT); or R.N. may, by completing the twelve month training program, qualify for registration in Nuclear Medicine Technology.

V. Curriculum

The following suggested basic minimum curriculum is presented as a guide for an educational program in nuclear medicine technology. The designation of technologist applies to those holding a bachelor or higher degree in science. Only the minimum essentials or requirements for a program of nuclear medicine technology education are suggested, so a curriculum beyond that necessary for an associate degree (technician) is not suggested in these essentials. The final distinction between technologist and technician lies in the purview of the certifying registry.

B. The training program must be at least twelve months in duration, should be uninterrupted, and should include approximately 300 didactic hours, or more where the clinical training is part of a total integrated educational program leading to an associate degree or baccalaureate.

C. Adequate clinical experience should be provided. The instruction should follow a planned outline and include text assignments, lectures, discussions, demonstrations, supervised practice, practical examinations, and quizzes.

Curriculum:

1. Orientation and Introduction (4 hours)
2. Basic Anatomy, Physiology, and Pathology (40-100 hours)
3. Mathematics (20 hours)
4. Radiation Physics (10-20 hours)
5. Nuclear Physics and Instrumentation (60-100 hours)
6. Radiation Biology (20-30 hours)
7. Radiation Protection (15 hours or minimum for Federal or State laws)
8. Basic Laboratory Procedures and Techniques (10-50 hours)
9. Clinical Application of Radionuclides (100-150 hours)
10. Records and Administrative Procedures (5 hours) Presentation of regulatory requirements relating to licensing and inspection.
11. Therapeutic Radionuclides (10 hours)
12. Radiochemistry and Radiopharmaceuticals (25 hours)

The hours indicated are only suggestions and not essential provided an adequate total educational program is offered.

VI. Ethics

Excessive student fees and commericial advertising are considered unethical. Educational programs must not substitute students for paid technologists and technicians.

VII. Health

Applicants for admission to an acceptable educational program shall be required to submit evidence of good health and successful vaccinations, and a report of a medical examination should be a part of student records. This examination shall include an x-ray of the chest. Health care and hospitilization shall be available to the student.

VIII. Admission To The Approved List

Application for approval of an educational program in nuclear medicine technology should be submitted to the Department of Allied Medical Professions and Services, Division of Medical Education, American Medical Association, 535 North Dearborn Street, Chicago, Illinois 60610. Forms will be supplied for this purpose on request and should be completed by the director of the institution requesting approval.

Approval may be withdrawn whenever, in the opinion of the Council on Medical Education, a school does not maintain an educational program in accordance with the minimum standards stated above.

ACCREDITATION OF ALLIED MEDICAL EDUCATIONAL PROGRAMS

OCCUPATIONS for which educational programs are accredited by the AMA and collaborating organizations:

1. Certified Laboratory Assistant
2. Cytotechnologist
3. Inhalation therapy Technician
4. Medical Assistant
5. Medical Record Librarian
6. Medical Record Technician
7. Medical Technologist
8. Nuclear Medicine Technician
9. Nuclear Medicine Technologist
10. Occupational Therapist
11. Physical Therapist
12. Radiation Therapy Technologist
13. Radiologic Technologist

ORGANIZATIONS collaborating on the accreditation of educational programs for the allied medical occupations listed above:

1. American Academy of Orthopaedic Surgeons
2. American Association for Inhalation Therapy
3. American Association of Medical Assistants
4. American Association of Medical Record Librarians
5. American College of Chest Physicians
6. American College of Radiology
7. American Medical Association
8. American Occupational Therapy Association
9. American Physical Therapy Association
10. American Society of Anesthesiologists
11. American Society of Clinical Pathologists
12. American Society of Medical Technologists
13. American Society of Radiologic Technologists
14. Society of Nuclear Medical Technologists
15. Society of Nuclear Medicine

NOTE: The AMA Council on Medical Education and these collaborating organizations are recognized by the National Commission on Accrediting and the U.S. Office of Education to accredit educational programs for a growing list of allied medical occupations.

APPENDIX B

Regulatory Bodies in the Field of Nuclear Medicine Technology

Regulatory Bodies in the Field of Nuclear Medicine Technology

It is important for an administrator to know how the field of nuclear medicine technology is regulated. There are three aspects which will be considered here:

- certification of NMTs,
- accreditation of hospital nuclear medicine services, and
- accreditation of NMT educational programs.

At the present there is no joint registry for certifying NMTs. Two separate registries represent the two major disciplines that fed into nuclear medicine: radiology and clinical pathology. These are the American Registry of Radiologic Technologists (ASRT), 2600 Wayzata Boulevard, Minneapolis, Minnesota 55405, and the American Society of Clinical Pathologists (ASCP), 2100 West Harrison Street, Chicago, Illinois 60612. A list of the required qualifications for applicants for the registry examination can be obtained directly from each of the above bodies. Examinations are given periodically in all regions.

The quality of hospital nuclear medicine services is controlled by the Joint Commission on Accreditation of Hospitals, 645 North Michigan Avenue, Chicago, Illinois 60611. In their 1970 Accreditation Manual for hospitals, standards for organizing and operating a Nuclear Medicine Service are spelled out in detail.

Standards for NMT educational programs have been established by the AMA Council on Medical Education based upon recommendations of a review committee of all of the professional societies with interests in the field of nuclear medicine. The six societies are:

American College of Radiology	ACR
American Society of Clinic Pathologists	ASCP
Society of Nuclear Medicine Technologists	SNMT
American Society of Radiologic Technologists	ASRT
American Society of Medical Technologists	ASMT
Society of Nuclear Medicine	SNM

This Joint Review Committee on Education Programs in Nuclear Medicine Technology also sponsors review committees which review educational programs applying for accreditation. The standards are requirements for an approve program are set out in a document entitled "Essentials of an Accredited Program in Nuclear Medicine Technology," which was approved by the AMA House of Delegates in July, 1969. (See Appendix A.)

APPENDIX C

Sample School and Hospital Affiliation Agreement

Springfield
Technical Community College
ARMORY SQUARE, SPRINGFIELD, MASSACHUSETTS 01105 • TELEPHONE (413) 781-6470

OFFICE OF THE PRESIDENT

C-1

Dear

The increased interest in health technology programs within the Massachusetts Community College system has identified the need for standardized contractual agreements with our cooperating affiliating agencies.

With approval of the Massachusetts Board of Regional Community Colleges, the attached AGREEMENT is forwarded herewith for your consideration and approval.

Following a period of pre-clinical academic studies, it is felt that technical skills can best be identified within a clinical environment. Herein the student learns the complexity of the total health program and has an opportunity to develop job competencies under the supervision of professional personnel. Thus we may develop a more realistic approach to the importance of the supportive worker's place on the Health Team.

Clinical areas proposed for externship experience:

Course	Date	
	From	To

Upon return of this Agreement, the Program Chairman will coordinate the number of students to be assigned and a suggested rotation schedule mutually agreed upon by the department Supervisor.

We are grateful for your interest and cooperation in assisting us to prepare the best possible personnel to meet the ever rising health care needs in our community.

Sincerely,

Edmond P. Garvey
President

EPG:bbd
Encls.

A MASSACHUSETTS REGIONAL COMMUNITY COLLEGE

C-2

AGREEMENT

between ____
(name of school)

and ____
(name of hospital)

for Co-operative Health Education Programs

This AGREEMENT made and entered into this ___ day of _______, 1971 by and between ___________________, hereinafter referred to as the College and
(name of school)

______________________, hereinafter referred to as the agency
(name of hospital)

WITNESSETH:

WHEREAS, the College is the owner and operator of a Health Technology Educational Program in ____ requiring certain clinical/educational facilities, and,

WHEREAS, the Agency is the owner and operator of an institution in which such clinical/educational facilities exist, and

WHEREAS, the parties herein referred to are desirous of entering into this Agreement for the express purpose of setting forth clearly and accurately a complete and detailed statement of their respective agreements and responsibilities in connection with said Program between the parties during the term of the Agreement;

NOW THEREFORE, in consideration thereof, the College and the Agency functioning collaboratively, herein agree to carry out the responsibilities as set forth in this Agreement.

The College agrees to:

1. Assume and maintain full responsibility for the planning and execution of the Program, including programming, administration, curriculum content, faculty appointments, faculty administration, and the requirements for matriculation, promotion, and graduation.

2. Provide orientation to the educational program for the Agency staff.

3. Clear each student for physical fitness and provide certification that the student has been immunized against the common communicable diseases.

4. Require each student and instructor to have health and accident insurance coverage and, where required, professional liability insurance.

5. Reach a mutual agreement with the Agency regarding days and hours for student assignments to clinical/educational areas and also be responsible for planning and coordinating clinical assignments at the Agency. All plans for observations and/or clinical experience shall be subject to the approval of the Agency.

6. Request that students and instructors respect and preserve the confidential nature of all medical and personal information relating to the patients in the Agency.

7. Withdraw any instructor or student from the clinical area when the instructor or student is unacceptable and undesirable to the Agency for reasons of health, performance of duties, or other reasonable cause.

8. Require that student and instructors comply with all rules and regulations of the Agency while present there.

The Agency agrees to:

1. Allow the students enrolled at the College to utilize the facilities and resources of the Agency, including supplies and equipment that are essential for this supervised clinical/educational experience under Agency personnel.

2. Make available sufficient diverse areas and units of the Agency to the students to assure adequate choice of learning experiences essential to implementation of educational objectives.

3. Provide adequate classrooms and/or conference rooms, suitable dressing rooms and/or lockers for students and instructors.

4. Permit the use of its cafeteria, library, and parking facilities, if any, by students and instructors.

5. Provide first-aid treatment to students needing such care, but the Agency shall not be obligated to furnish any other medical or surgical service.

6. Provide for orientation of newly appointed faculty members concerning the policies and procedures of the Agency.

7. Provide the above at no cost to the College or to the Massachusetts Board of Regional Community Colleges.

8. Plan to meet periodically with designated faculty members of the College to discuss and evaluate the student program.

It is mutually agreed that:

1. Representatives of the College and Agency shall meet at least annually to discuss issues of mutual concern and to decide whether or not any changes are necessary in the Program or this agreement.

2. Students and instructors shall under no circumstances be deemed employees of the Agency, but rather as privileged associates of the Agency during the hours in which they are assigned to the Program. Neither party to this agreement shall be obligated to pay any monetary compensation to the other party or any student.

3. The Program shall be the responsibility of, and under the control and supervision of the College and shall be administered through its staff, but this is not intended to mean that instructors from the College will be present while the student is at the Agency.

An outline of the purposes of the Program is attached hereto as Exhibit "A". This AGREEMENT shall become effective on __________, 19__, and shall continue in effect for a period of one year and reviewed and renewed annually. This AGREEMENT may be modified by mutual consent of both contracting parties at any time during the period of contractual agreement. If either party desires to terminate this AGREEMENT, it shall serve ninety (90) days' written notice thereof on the other party, however, the parties agree that if an academic semester has commenced, such notice shall not be effective until completion of that semester.

IN WITNESS WHEREOF, the parties hereto have set their hands and seals the day and year first above written.

(name of school)	(name of hospital)
By ______________________ President of School	By ______________________ Hospital Administrator
By ______________________ Faculty Program Coordinator	By ______________________ Department Supervisor

I CERTIFY THAT ______________________ has authority to execute the above contract.

____

This Agreement approved as to form by the Massachusetts Board of Regional Community Colleges on November 3, 1971.

SPRINGFIELD TECHNICAL COMMUNITY COLLEGE

Armory Square • Springfield, Massachusetts 01105, Tel. (413) 781-6470

EXHIBIT "A"

THE PURPOSE OF THIS AGREEMENT is to provide the student of the program an opportunity to:

☐	CERTIFIED LAB. ASSISTANT:	Gain medical laboratory technical experience in an actual clinical facility under the direct supervision of a Registered Medical Technologist. A list of C.L.A. tasks and functions as approved by the Board of Certified Laboratory Assistants will be provided.
☐	DENTAL ASSISTANT:	To provide an opportunity for observation as well as practical chairside experience in the areas of general and specialized dentistry under the supervision of qualified professional personnel.
☐	DENTAL HYGIENIST:	To gain experience first by observing and then by assisting the dentist in operative procedures, periodontal treatment and oral surgery. To gain further experience in providing preventive dental care to patients. This is to be done under the direct supervision of a licensed dentist or a member of the dental hygiene faculty.
☐	INHALATION THERAPY TECH.:	Carry out treatments within the purview of the Inhalation Therapy Technicians planned and supervised by a Registered Chief Therapist and the Anesthesiology Department. A list of Inhalation Therapy Technicians' tasks and functions as outlined in the "Guidebook for an Approved School of Inhalation Therapy," formulated by the Board of Schools of Inhalation Therapy, will be provided.
☐	MEDICAL ASSISTANT:	To gain experience by observing and then assisting the physicians in clinical areas related to the Medical Assistant field. A list of tasks and/or functions of which the students are capable will be provided.

☐ MENTAL HEALTH TECHNICIAN:	To develop technical skills and job competencies in human services through supervised practicum experience. The student will acquire a realistic perception and knowledge of the supportive worker's duties and responsibilities in the spectrum of community services by participating in a cooperatively planned practicum, under the supervision and direction of professional staff members of the agency. Specific objectives and learning opportunities will be defined by faculty and agency staff.
☐ OPERATING ROOM TECHNICIAN:	Observe and to assist the surgeon and other members of the surgical team in the Operating Room and Delivery Room under the direct supervision of Registered Professional Nurses. A list of Operating Room Technicians' procedures and operations as recognized by the Association of Operating Room Nurses, Inc., 575 Madison Avenue, New York, N. Y., will be provided.
☐ PHYSICAL THERAPY ASSISTANT:	Carry out treatments within the purview of the Physical Therapy Assistant, planned and supervised by a Registered Physical Therapist, develop an understanding of mental and emotional problems and appreciate other phases contributing to patient care. A list of Physical Therapy Assistant tasks and functions as approved by the Board of Directors of the American Physical Therapy Association, 1740 Broadway, New York, N. Y., will be provided.
☐ RADIOLOGIC TECHNOLOGY:	Obtain experience in the practical aspects of Radiologic Technology; to develop skills in Radiologic Technology; and to adjust to the clinical environment of a hospital as a member of the health team.

# # # # #

Appendix D

Sample Questionnaire for Assessing the Need for an NMT Program and Available Clinical Resources

________________________________ Community College is considering the establishment of a two-year Nuclear Medicine Technology program.

The information we are requesting will help us determine if a new program is advisable and feasible in this area. Your answers will be held in the strictest confidence.

Thank you very much for assisting us.

Respondent: Name ______________________________

Title ______________________________

Hospital ______________________ No. of beds _____

Address ______________________________

Are nuclear medicine facilities available on the premises?

_____ YES _____ NO If NO, please return the questionnaire but DO NOT complete it.

Thank you.

Organization & Staff

Organization of nuclear medicine services (check one)

- ☐ Separate department
- ☐ Division of Radiology
- ☐ Division of Pathology
- ☐ Other ______________________________

Please indicate number of nuclear medicine staff at your hospital

	NUMBER	
	Fulltime	Parttime
Physicians		
Physicists		
Radiopharmacists		
Radiochemists		
Chief NMT		
Staff NMTs		
NMT Trainees		
Orderlies		
Secretary-receptionist		
Other (Identify)______________		

Present Nuclear Medicine Equipment and Services

Please indicate numbers of each type of equipment operational in your hospital.

	Number
Rectilinear Scanners	______
Gamma Cameras	______
Uptake probes	______
Dose calibrators	______
Gamma well Counters	______
Liquid Scintillation Counters	______
Computers	
Other (Identify) ____	______

How many scanning procedures does your department do per year?

Brain	______
Liver/spleen	______
Thyroid	______
Lung	______
Bone	______
Heart	______
Whole body	______
Other (Identify) ____	______
____	______
____	______
____	______
____	______
____	______
____	______
____	______

How many of each of the following procedures does your laboratory do each year?

T_3/T_4	______
Blood volume	______
Plasma volume	______
Radioimmunoassay	______
Chillings	______
Ferrokinetics	______
Other (Identify) ____	______

History and Future Projection

Has your hospital been providing nuclear medicine services for more than two years?

_____ YES _____ NO

Do you plan to expand your Nuclear Medicine Department?

Staff _____ YES _____ NO
Equipment _____ YES _____ NO
Procedures _____ YES _____ NO

Advancement Opportunities for NMTs

What is the salary range at your hospital for employment of a certified NMT with no working experience?

$ _______________ to $ _______________

What is the salary range for the chief NMT?

$ _______________ to $ _______________

Training Program

Does your Department currently have a training program for NMTs?

_____ YES _____ NO

If YES, what type(s)?

_____ None
_____ On-the-job training only
_____ Certificate program (describe entry requirements and length)
____
____
_____ A.S. Degree Program in collaboration with _______________ (name of school)
_____ B.S. Degree Program in collaboration with _______________ (name of school)
_____ Other (Identify) ____

Thank you for taking the time to supply this information which has helped us to know you better. I am ecnlosing some information about our school so that you may also know more about us.

Please indicate whether or not you are interested in discussing possible affiliation with our school for an associate degree program in NMT.

_____ YES, I would like to meet with you to discuss this possibility.
_____ NO, we have no interest at this time.

Please make any additional comments

NOTE TO ADMINISTRATOR.

In liew of mailing a questionnaire, a representative of the college might call the area hospitals to personally obtain this information.

APPENDIX F

Professional Societies
Pertinent to the Education of
Nuclear Medicine Technicians

Professional Societies Pertinent to the Education of Nuclear Medicine Technicians

The following list of educational, technical, and medical societies should be of value to the administrator or instructor of an NMT education program.

Further information concerning local chapters, dues, national conventions, etc., can be obtained by writing The Executive Secretary.

AMERICAN ASSOCIATION OF COMMUNITY AND JUNIOR COLLEGES (AACJC) Formerly (AAJC) One Dupont Circle, N.W., Suite 410, Washington, D. C. 20036

History: Founded in 1920. A non-profit national professional association.

Purpose: To develop strong programs of preservice and in-service preparation for faculty, experiment with and evaluate teacher organization and practices, and to attract promising men and women to the field. To improve student personnel services with particular regard to counseling and guidance. To stimulate creation of well-conceived curricula, especially in technical and semi-professional education and community services. To bring about accurate and positive perceptions of community and junior colleges among various publics. To assist in the formulation of sound laws and regulations at state and local levels for establishment and development of two-year colleges. To promote effective relationships with high schools, universities, and professional and trade organizations. To effect preparation of a growing supply of well-qualified administrators. Action on such matters as financing higher education, issues in the independent junior college sector, international programming, and federal activity with regard to education.

Membership: 916. Staff 55.

Qualifications for Membership: Basic membership is limited to community and junior colleges, and similar institutions, which are exempt from federal income taxation and which are not private foundations. Membership consists of two categories, full and provisional, with all members approved by the Board of Directors. Individuals may join the Association as associates; foundations, corporations, etc., as institutional associates.

Publications: Community and Junior College Journal; Community and Junior College Directory; newsletters, bulletins, handbooks, guides, and reports on various aspects of the community and junior college.

AMERICAN COLLEGE OF NUCLEAR PHYSICIANS (ACNP) (Formerly: College of Nuclear Physicians), P. O. Box 1245, Berkley, Michigan 48072

History: Organized in 1974 as ACNP. Incorporated in the State of Illinois.

Purpose: To foster highest standards of nuclear medicine service and consultation to the public, hospitals, and referring physicians. To advance the science of nuclear medicine and, through study, education, and improvement of the socioeconomic aspects of the practice of nuclear medicine, to improve nuclear medicine consultation and service. To promote the continuing competence of practitioners of nuclear medicine.

Membership: 1300 responses to a questionnaire.

Qualifications for Membership: A licensed physician shall be eligible for membership provided he is actively engaged in the practice of nuclear medicine and is certified by an *American medical specialty board* or other certifying body judged of equivalent standards by the Board of Regents for outstanding contributions to the specialty. Categories of membership are: Member, Honorary member, Emeritus member, Fellow, Inactive member and Associate (for those who are board eligible and for those in training).

Publications: None.

AMERICAN SOCIETY OF ALLIED HEALTH PROFESSIONS
1 Dupont Circle, Suite 300, Washington, D. C. 20036

History: Founded September 15, 1967.

Purpose: To provide a medium for cooperation and communication and to give leadership to educational institutions, professional organizations, state associations, and other organizations devoted to education and related programs in allied health professions.

Membership: 200 institutions. 1,800 individuals.

Qualifications for Membership: Institutional; a school of allied health with clearly identifiable budgets and administrative structures for allied health educational programs; or nonprofit organizations with a serious interest in allied health education. Individual; is open to anyone with an interest in allied health education. Associate membership and sustaining memberships are for profit organizations, but do not have vote.

Publications: "Allied Health Trends," monthly newsletter; Journal of Allied Health, a quarterly publication.

AMERICAN SOCIETY OF CLINICAL PATHOLOGISTS (ASCP)
2100 West Harrison Street, Chicago, Illinois 60612

History: Founded May, 1922. Professional society of clinical pathologists.

Purpose: "The corporation is organized exclusively for charitable, educational, and scientific purposes including the following: (a) to promote the public health and safety by a wider application of pathology to the diagnosis and treatment of disease, (b) to stimulate research in all branches of pathology, (c) to establish standards for performance of various laboratory procedures, (d) to conduct seminars and other educational programs and to prepare, publish, and disseminate educational materials designed to acquaint pathologists, medical technologists, and other laboratory personnel with scientific developments in the field of clinical laboratory medicine, (e) to establish or participate in the establishment of voluntary standards and curricula for the training of medical technologists and other paramedical laboratory personnel and to prepare and furnish lists of institutions which comply with such voluntary standards, (f) to establish and maintain a voluntary program for the examination and certification of medical technologists and other paramedical laboratory personnel, including the maintenance of a registry wherein paramedical laboratory personnel who voluntarily seek to be registered may, upon meeting (and continuing to meet) the standards established by the Society, be registered, and (g) to make distributions to organizations that qualify as exempt organizations under section 501 (c) (3) of the Internal Revenue Code of 1954, or the corresponding provision of any future United States Internal Revenue Law."

Membership: Approximately 19,700. 1 local section.

Qualifications for Membership: Fellowship is limited to pathologists who have been certified by the American Board of Pathology; associate members are other legally qualified physicians and those holding an academic doctorage acceptable to the Board of Censors; junior members are physicians training for careers in pathology who are, or have been, enrolled in a training program recognized by the American Board of Pathology; affiliate members include all persons who have been certified in one or more of the technical categories designated by the ASCP and who are currently registered with the Board of Registry.

Publications: American Journal of Clinical Pathology; Laboratory Medicine

AMERICAN SOCIETY FOR HEALTH MANPOWER EDUCATION AND TRAINING (ASHET) (Formerly: American Society for Hospital Education and Training, part of the American Hospital Association) 840 North Lake Shore Drive, Chicago, Illinois 60611

History: Founded in 1970.

Purpose: To foster professional development of members; to demonstrate the value of comprehensive education as a management strategy; to promote the concept of the need for continuing education among all health care personnel; to develop coordination among organizations that are involved in the education of health care personnel; to formulate programs of information and evaluation of educational resources; to participate actively in and recommend action on national issues relating to manpower and education of health care personnel.

Membership: 1,300

Qualifications for Membership: Must be employed in a health care institution or related health organization with continuing responsibilities related to education and training within that institution or organization, must be employed for similiar purposes by organizations mandated by legislation or health-related educational trusts, or must be an educational institution faculty member with a primary role in the training or continuing education of health care personnel. Associate membership is available for those individuals who are administratively responsible for the education and training function, or are producers and providers of materials, programs, and services related to the education and training of health care personnel. Student membership is available to students in academic programs in education or one of the health manpower disciplines.

Publications: Members receive personal copies of Hospitals, the Journal of the American Hospital Association, the Week in Hospitals, and Cross-Reference.

AMERICAN SOCIETY FOR MEDICAL TECHNOLOGY (ASMT)
555 West Loop South, Suite 200, Bellaire, Texas 77401

History: Founded in 1932.

Purpose: To establish, develop, and maintain the highest standards in clinical laboratory methods and research; create mutual understanding and cooperation between those in the laboratory and all health professionals working in the interest of individual and public health; promote programs of primary and continuing education, research, and development; represent the profession of medical technology through improvement of the status of its members; advance the ideals and principles of the profession of medical technology.

Membership: 18,883. Staff 40.

Qualifications for Membership: Active membership - Baccalaureate in Medical Technology plus certification or experience; or associate degree with clinical training program approved by agencies recognized by ASMT. Student membership enrolled in a medical technology program at an accredited college or university; or a structured program of training conducted by agencies recognized by ASMT.

Publications: American Journal of Medical Technology, published monthly. Cadence, bi-monthly; ASMT News, monthly.

AMERICAN SOCIETY OF RADIOLOGIC TECHNOLOGISTS (ASRT)
500 North Michigan Avenue, Chicago, Illinois 60611

History: Founded in 1920. Professional society of x-ray technologists.

Purpose: "To advance the science of radiologic technology, to establish and maintain high standards of education and training, to elevate the quality of patient care and to improve the welfare and socioeconomics of radiologic technologists."

Membership: 13,338. 9 staff. 54 State Societies.

Qualifications for Membership: Active-registered and in good standing with ARRT; licensed technologists in N. J., Calif., and New York; Associates-instructors in AMA-approved programs; Student members-students in state-approved or AMA-approved programs.

Publications: ASRT Scanner (newsletter), bimonthly; Radiologic Technology, (Journal of the American Society of Radiologic Technologists), bimonthly.

AMERICAN VOCATIONAL ASSOCIATION (AVA)
1510 H Street, N. W., Washington, D.C. 20005

History: Founded in 1925. 78 state groups.

Purpose: Professional association devoted exclusively to the promotion and development of vocational, technical, and practical arts education.

Membership: 52,000 plus.

Qualifications for Membership: Teachers, administrators, supervisors, researchers, teacher educators, curriculum development specialists, and guidance counselors working in comprehensive and vocational high schools, vocational-technical schools, junior and community colleges, technical institutes, colleges and universities, state education agencies, and manpower development and training programs. Associated membership also comes from business, industry, labor, advisory committees, school boards, and elsewhere outside the field of education. There are eight classifications (Affiliated Membership, Direct Membership, Student Membership, Loyalty Membership, Associate Lay Membership, Life Membership, Associate State Membership [Group], Associate National Membership [Group]) each with varying qualifications.

Publications: Newsletter; American Vocational Journal; also publishes series of bulletins on vocational education.

ASSOCIATION OF RADIOPHARMACEUTICAL SCIENTISTS (Has approval and support of the leadership of SNM but will be viable independently. International Symposium in Atlanta, where an open forum for discussion of the proposed association was held on February 13, 1974.)
Hospital of the University of Pennsylvania, Department of Radiology,
Philadelphia, Pennsylvania 19174

History: Proposed in February of 1974.

Purpose: The maintenance of high standards of radiopharmaceutical quality. To voice an opinion relative to the impact of economic, legislative, and interprofessional factors upon those engaged in the radiopharmaceutical sciences; to establish a means for discussing aspects of practice, issues, and problems of mutual interest and concern; to promote professional development through the conduct of educational and scientific meetings and activities; to enhance the effectiveness of health care delivery in nuclear medicine by promoting the highest standards of professional practice in the radiopharmaceutical sciences.

Membership:

Qualifications for Membership: Membership in the organization is limited to holders of a B.S. or higher degree, or their equivalent, and whose training, experience or occupation relate to radiopharmaceuticals. Two categories of members, Radiopharmaceutical Scientist Members and Student Members.

Publications: (Proposed) To publish Association newsletters, to publish an International Radiopharmaceutical Journal, to communicate all related radiopharmaceutical information to the Association.

HEALTH PHYSICS SOCIETY (HPS)
P. O. Box 156, East Weymouth, Massachusetts 02189

History: Founded 1956.

Purpose: To develop scientific knowledge and practical means for the protection of man and his environment from the harmful effects of radiation, while encouraging its optimum utilization for the benefit of mankind; to improve public understanding of the problems and needs in radiation protection; to promote health physics as a profession.

Membership: 3,000. 30 Local chapters.

Qualifications for Membership: There are Members, Corresponding Members, Associate Members, Student Members, Members Emeritus, Life Members, and Affiliate Members with varying qualifications.

Publications: Newsletters, irregular; Health Physics Journal, monthly; Membership Handbook, annual.

TECHNOLOGIST SECTION, SOCIETY OF NUCLEAR MEDICINE (SNM)
305 East 45th Street, New York, New York 10017

History: Founded 1971.

Purpose: To promote the professional development of nuclear medicine technologists and provide a means for communication and exchange of ideas and information.

Membership: 1,250. 16 local sections.

Qualifications for Membership: Membership in the Society of Nuclear Medicine and training and/or experience in nuclear medicine technology satisfactory to the Membership Committee.

Publications: Journal of Nuclear Medicine Technology.

APPENDIX F

AEC Application for Byproduct Material License

Form AEC-313b (M)
(2-71)
10 CFR 30

UNITED STATES
ATOMIC ENERGY COMMISSION

INSTRUCTIONS FOR PREPARATION OF APPLICATION FOR BYPRODUCT MATERIAL LICENSE FORM AEC-313 and 313a

GENERAL INFORMATION

An applicant for a "Byproduct Material (Radioisotopes) License" should complete Form AEC-313 in detail and submit in duplicate to the United States Atomic Energy Commission. The applicant should endeavor to cover his entire radioisotope program with one application, if possible. However, separate applications should be submitted for medical teletherapy and gamma irradiators. Supplemental sheets may be appended when necessary to provide complete information. *Item 16 must be completed on all applications. Submission of an incomplete application will often result in a delay in issuance of the license because of the correspondence necessary to obtain information requested on the application.*

NOTE.—When the application includes one of the special uses listed below, the applicant should request the appropriate pamphlet which provides additional instructions:

1 Industrial Radiography—"Licensing Requirements for Industrial Radiography" (use application Form AEC-313R for Radiography);

2 Teletherapy — "Licensing Guide — Teletherapy Programs;"

3 Broad License (research and development) — "Licensing Guide for Type-A Licenses of Broad Scope for Research and Development;" and

4 Broad License (medical uses) — "Licensing Guide for Broad Medical Programs."

The Commission charges fees for filing of applications for licenses as specified in Section 170.12, Title 10, Code of Federal Regulations, Part 170. The applicant should refer to Section 170.31, *Schedule of fees for materials licenses*, to determine what fee should accompany the application. No action can be taken on applications until fees are paid. Checks or money orders should be made payable to the U.S. Atomic Energy Commission.

The Form AEC-313a should be completed in detail each time a medical request is made for a human use of radioisotopes. Two copies of the completed Form AEC-313 and 313a (if a medical application) and two copies of each attachment thereto, should be sent to the U.S. Atomic Energy Commission, Directorate of Licensing, Washington, D.C., 20545. One copy should be retained for the applicant's file.

EXPLANATION OF FORM AEC-313

Item No.

1 (*a*) The "applicant" is the organization or person legally responsible for possession and use of the byproduct material specified in the application.

(*b*) Indicate other address(es) at which byproduct material will be used if different from that listed in 1(*a*). A post office box number is not acceptable.

2 The "department" is the department or similar subdivision where the byproduct material will be used.

3 Self-explanatory.

4 The "individual user" is the person experienced in use and safe handling of radioisotopes. *If the application is for "human use," the individual user must be a physician licensed by a State or Territory of the United States to dispense drugs in the practice of medicine and have extensive experience for each proposed clinical use.*

5 Self-explanatory.

6 (*a*) List by name each radioisotope desired, such as "Carbon 14," "Cobalt 60," etc.

(*b*) List chemical and/or physical form for *each* radioisotope and the quantity of *each* which the applicant desires to possess at any one time. If more than one chemical or physical form of a particular radioisotope is desired, a *separate* possession limit should be stated for each form. For example, an applicant desiring to use two chemical forms of Iodine 131 must specify both forms and a possession limit for *each* form. Example:

Iodine 131	Iodide	10 millicuries
Iodine 131	Iodinated Human Serum Albumin	1 millicurie
Krypton 85	Gas	1000 millicuries

If the byproduct material is to be obtained as a sealed source(s), specify the manufacturer, model number, and amount of activity in *each* sealed source. Example:

Cobalt 60	3 Sealed Sources, 100 mc each (Iso Corp. Model Z-54)	300 millicuries

7 State the use of each byproduct material and chemical form specified in Item 6(*a*) and (*b*). If the radioisotope is for "human use," *do not complete this item; complete Form AEC-313a, Supplement A—Human Use.*

8-9 These items must be completed for *each* individual named in Item 4. If more than one individual is listed in Item 4, clearly key the name of each individual to his experience.

10-16 Self-explanatory.

Form AEC-313
(2-73)
CFR 30

UNITED STATES ATOMIC ENERGY COMMISSION

APPLICATION FOR BYPRODUCT MATERIAL LICENSE

Form approved
Budget Bureau No. 38-R0027

INSTRUCTIONS.—Complete Items 1 through 16 if this is an initial application or an application for renewal of a license. Information contained in previous applications filed with the Commission with respect to Items 8 through 15 may be incorporated by reference provided *references are clear and specific.* Use supplemental sheets where necessary. Item 16 must be completed on all applications. Mail two copies to: U.S. Atomic Energy Commission, Washington, D.C., 20545, Attention: Materials Branch, Directorate of Licensing. Upon approval of this application, the applicant will receive an AEC Byproduct Material License. An AEC Byproduct Material License is issued in accordance with the general requirements contained in Title 10, Code of Federal Regulations, Part 30, and the Licensee is subject to Title 10, Code of Federal Regulations, Part 20, and the license fee provisions of Title 10, Code of Federal Regulations, Part 170. The license fee category should be stated in Item 16 and the appropriate fee enclosed. (See Note in Instruction Sheet).

1. (a) NAME AND STREET ADDRESS OF APPLICANT. *(Institution, firm, hospital person, etc. Include ZIP Code and telephone number.)*

(b) STREET ADDRESS(ES) AT WHICH BYPRODUCT MATERIAL WILL BE USED. *(If different from 1(a). Include ZIP Code.)*

2. DEPARTMENT TO USE BYPRODUCT MATERIAL

3. PREVIOUS LICENSE NUMBER(S). *(If this is an application for renewal of a license, please indicate and give number.)*

4. INDIVIDUAL USER(S). *(Name and title of individual(s) who will use or directly supervise use of byproduct material. Give training and experience in Items 8 and 9.)*

5. RADIATION PROTECTION OFFICER. *(Name of person designated as radiation protection officer if other than individual user. Attach resume of his training and experience as in Items 8 and 9.)*

6. YPRODUCT MATERIAL. *(Elements and mass number of each.)*

(b) CHEMICAL AND/OR PHYSICAL FORM AND MAXIMUM NUMBER OF MILLICURIES OF EACH CHEMICAL AND/OR PHYSICAL FORM THAT YOU WILL POSSESS AT ANY ONE TIME. *(If sealed source(s), also state name of manufacturer, model number, number of sources and maximum activity per source.)*

7. DESCRIBE PURPOSE FOR WHICH BYPRODUCT MATERIAL WILL BE USED. *(If byproduct material is for "human use," supplement A (Form AEC-313a) must be completed in lieu of this item. If byproduct material is in the form of a sealed source, include the make and model number of the storage container and/or device in which the source will be stored and/or used.)*

(Continued on reverse side)

TRAINING AND EXPERIENCE OF EACH INDIVIDUAL NAMED IN ITEM 4 *(Use supplemental sheets if necessary)*

8. TYPE OF TRAINING	WHERE TRAINED	DURATION OF TRAINING	ON THE JOB *(Circle answer)*	FORMAL COURSE *(Circle answer)*
a. Principles and practices of radiation protection			Yes No	Yes No
b. Radioactivity measurement standardization and monitoring techniques and instruments			Yes No	Yes No
c. Mathematics and calculations basic to the use and measurement of radioactivity			Yes No	Yes No
d. Biological effects of radiation			Yes No	Yes No

9. EXPERIENCE WITH RADIATION. *(Actual use of radioisotopes or equivalent experience.)*

ISOTOPE	MAXIMUM AMOUNT	WHERE EXPERIENCE WAS GAINED	DURATION OF EXPERIENCE	TYPE OF USE

10. RADIATION DETECTION INSTRUMENTS. *(Use supplemental sheets if necessary.)*

TYPE OF INSTRUMENTS *(Include make and model number of each)*	NUMBER AVAILABLE	RADIATION DETECTED	SENSITIVITY RANGE *(mr/hr)*	WINDOW THICKNESS *(mg/cm²)*	USE *(Monitoring, surveying, measuring)*

11. METHOD, FREQUENCY, AND STANDARDS USED IN CALIBRATING INSTRUMENTS LISTED ABOVE.

12. FILM BADGES, DOSIMETERS, AND BIO-ASSAY PROCEDURES USED. *(For film badges, specify method of calibrating and processing, or name of supplier.)*

INFORMATION TO BE SUBMITTED ON ADDITIONAL SHEETS IN DUPLICATE

13. FACILITIES AND EQUIPMENT. Describe laboratory facilities and remote handling equipment, storage containers, shielding, fume hoods, etc. Explanatory sketch of facility is attached. *(Circle answer)* Yes No

14. RADIATION PROTECTION PROGRAM. Describe the radiation protection program including control measures. If application covers sealed sources, submit leak testing procedures where applicable, name, training, and experience of person to perform leak tests, and arrangements for performing initial radiation survey, servicing, maintenance and repair of the source.

15. WASTE DISPOSAL. If a commercial waste disposal service is employed, specify name of company. Otherwise, submit detailed description of methods which will be used for disposing of radioactive wastes and estimates of the type and amount of activity involved.

CERTIFICATE (This item must be completed by applicant)

16. THE APPLICANT AND ANY OFFICIAL EXECUTING THIS CERTIFICATE ON BEHALF OF THE APPLICANT NAMED IN ITEM 1, CERTIFY THAT THIS APPLICATION IS PREPARED IN CONFORMITY WITH TITLE 10, CODE OF FEDERAL REGULATIONS, PART 30, AND THAT ALL INFORMATION CONTAINED HEREIN, INCLUDING ANY SUPPLEMENTS ATTACHED HERETO, IS TRUE AND CORRECT TO THE BEST OF OUR KNOWLEDGE AND BELIEF.

License Fee Category $ ____________

Fee Enclosed $ ____________

Date ______________________________

____
Applicant named in item 1

By: ______________________________

____
Title of certifying official

WARNING.—18 U. S. C., Section 1001; Act of June 25, 1948; 62 Stat. 749; makes it a criminal offense to make a willfully false statement or representation to any department or agency of the United States as to any matter within its jurisdiction.

APPENDIX G

An Annotated List of Audiovisual Suppliers

Appendix G - Annotated List of Audiovisual Suppliers

National Medical Audiovisual Center (Annex)
Station K
Atlanta, GA 30324

Send for their A.V. Cat. No. HE 20.3609/4:1973 Gpo Stock No. 1752-00149. $1.95 from Public Documents Distribution Center, 501 Tabor Avenue, Philadelphia, PA 19120. Their materials are available for free loan and includes 3-20 minute television programs on "Nuclear Medicine" on video tape or film prepared by R.J. Griep, M.D., W.B. Nelp, M.D., and T. G. Rudd, M.D., University of Seattle for the Washington/Alaska Regional Medical Program.

Society of Nuclear Medicine
305 East 45th Street
New York, NY 10017

One-hour teaching sessions on various subjects on slides and tape cassette available for purchase.

USAEC - TIC Film Library
P. O. Box 62
Oak Ridge, TN 37830

In "USAEC Combined Film Catalog, 1972," there are five films specifically on nuclear medicine in addition to more general titles on radiation physics and radiation protection. These films are available for free loan for public nonprofit exhibition.

U.S. Dept. of HEW
Public Health Service
Food & Drug Administration
Bureau of Radiological Health
1901 Chapman Avenue
Rockville, MD

A free catalog "Radiological Health Training Resources 1973" DHEW, Publication No. (FDA) 73-8034 available at the above address lists training fascicles, booklets, overhead projection transparencies, and 2x2 projection transparencies. Some of these materials would be useful in radiation physics, radiation protection, and radiation biology courses.

Additional Sources of audiovisual material:

- Manufacturers of nuclear medicine instrumentation
- Manufacturers of radiopharmaceuticals
- Commercial audiovisual rental agencies
- Private collections of slides used in existing NMT education programs.

APPENDIX H

List of NMT Program Planning Materials

Appendix H - List of Program Planning Materials

The following NMT program planning materials have been developed by TERC to assist administrators and planners to plan and implement nuclear medicine technology programs. These materials supplement this NMT Curriculum Guide and are available from TERC.

DIGEST OF EDUCATIONAL PROGRAMS: NUCLEAR MEDICINE TECHNOLOGY (1974)

By listing all known NMT existing and planned programs, the Digest allows exchange of information among program directors and collaboration between community college and hospital-based programs. The Digest is a useful resource for potential NMT students and career counselors.

CAREER LADDERS AND RECRUITMENT: NUCLEAR MEDICINE TECHNOLOGY 160 pp.

The Career Ladders section includes information gathered at three workshops concerned with the implementation of the career ladder concept in nuclear medicine technology. The Recruitment section includes information on materials and methods useful for recruitment of students into NMT programs.

CASE STUDIES 232 pp.

Nine programs are described in detail, including Hillsborough Community College (Tampa, Florida), and Denver Community College. These studies identify factors for administrators desiring to provide effective, cost-efficient education on the technical level.

RECRUITMENT BROCHURE: NUCLEAR MEDICINE TECHNOLOGY (1972)

Each brochure is a 5-fold single sheet. The recruitment brochure is a brief description of the nuclear medicine field designed to interest potential NMT's in the field. Included is a listing of NMT educational programs. Packages of 50.

A SOURCEBOOK OF WORKING PAPERS: NUCLEAR MEDICINE TECHNOLOGY (1971/72) 208 pp.

The sourcebook includes workshop reports, information on clinical training, the NMT Task List, Emerging Areas, Critical Incidents, and a report on NMT instructional materials.

For further information on these and other NMT program planning materials write to:

NMT Clearinghouse Coordinator
Technical Education Research Centers
44 Brattle Street
Cambridge, Massachusetts 02138